Technical Report

WATER AT A GLANCE

UTTARAKHAND

An assessment of Water Scarcity

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Foreword

The drinking water supplies in the mountains of Indian Himalaya are mostly dependent on natural springs, streams and rivulets. Over 50 percent of the local people of in the region depend on these natural water resources to meet their water requirements. However, during the last few decades, water discharges from these natural water resources are reported to be increasingly diminishing due to ever increasing anthropogenic and climatic pressure. As a result, fresh water scarcity throughout the Indian Himalaya has emerged as a major socio-environmental problem. Therefore, realizing the need to ensure long-term sustainability of fresh water supply to the Himalayan inhabitants, the GB Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Almora, under the over all guidance of Ministry of Environment, Forest & Climate Change (MoEFCC), GOI, has initiated Gram Jal Abhyaranya Programme that covers one identified districts in each of the 12 Indian Himalayan States. The programme also considers at least one drying spring in each of over 50,000 villages of the Indian Himalaya for rejuvenation. However, to successfully implement the Gram Jal Abhyaranya Programme in the region, a precedentary detail of fresh water scarcity assessment is necessary at administrative block level for each Indian Himalayan state. This report is, therefore, prepared to highlight the current situation of natural water sources used for fresh water supply in the state of Uttarakhand along with administrative block-wise geospatial assessment of water scarcity. The report is anticipated to be beneficial for proper field implementation of Jal Abhyaranya Programme. Moreover, the policy makers are also expected to be benefitted for developing sustainable fresh water management strategies. It is further proposed to continue with publication of such reports for remaining states of Indian Himalaya.

Dr. R.S. Rawal
(Director)

Preface

In spite of significant improvement with respect to distribution of fresh potable water to the residents of the India Himalayan region, a significant proportion of the Himalayan dwellers are still deprived of uninterrupted supply of fresh potable water through tapped schemes. Since, water supply in the IHR largely depends on climate sensitive natural water resources, such as rivulet, springs and streams, etc., a sustainable water management in the extremely mountainous terrain of Himalaya requires physical and social accounting of water based on availability and demand. As the physical water budgeting at a regional scale is extremely non-trivial, source-wise assessment of water supply schemes over the IHR, as an initiation to physical water accounting, is expected to highlight natural water resources that are majorly harvested and need immediate attention. Thus, this report is aimed to highlight the current situation of natural water sources used for tapped water supply for the state of Uttarakhand, and prioritized list of natural water resources harvested for maximum benefit to the society as well as under maximum usage threats. Moreover, the report is expected to shed light on fresh water vulnerability through an integrated index based approach wherein hydrological, environmental and demographic factors are integrated. Therefore, the report is anticipated to be extremely beneficial for policy makers for developing targeted intervention strategies for sustainable usages of water resources in the Indian Himalayas.

Table of Contents

1 Introduction

The Indian Himalaya contain over half the permanent snow and ice fields outside the Polar Regions. Consequently, the Himalayas are having more than 33,000 square km of glaciated basins that store approximately 12,000 cu. Km of fresh water[1] sustaining around 1.5 billion people of India, China, Nepal, Pakistan, Bhutan and Myanmar[2]. Around 16% of the total area of Hindu-Kush Himalaya is having fresh water wetlands, and more than 9000 glaciers could be found in the Indian Himalayan region (IHR)[3] along with numerous springs, streams and seepages serving as primary sources of fresh water. Although historically the water resources of mountains, such as springs, streams, rivulets, etc. were managed by the mountain community for sustainable usages, since the early 1970s these natural water resources of the Indian Himalayan regions are being tapped by Accelerated Rural Water Supply Programme (ARWSP) of state and regional governments so that uninterrupted fresh and potable water supply could be made. Currently, the National Rural Drinking Water Programme (NRDWP) is aimed at providing fresh potable water to natives of India including Himalayan dwellers. However, year-round uninterrupted availability of fresh potable water though piped government schemes to every household of the Indian Himalayan region remained a significant challenge, for example, as of 2013 a total of 26993 of 39142 habitations of Uttarakhand is having water supply coverage[4]. Water supply in the IHR through government schemes has experienced setbacks due to ineffective management and unaddressed logistical issues[5]. Moreover, with ever increasing water consumption trend, as global water demand is increasing with an annual rate of 1% during the last few decades[6], there is considerable pressure on individual water supply scheme.

Success and sustainability of a water supply schemes over the IHR is also dependent on the physical behavior of the natural water resources that are being tapped. Under the current context of climate change, wherein the Himalayas are having higher than the average global warming rate with enhanced negative impact of climate change on ecosystems and water resources[7,8,9], behaviors of these natural water resources are being increasingly becoming unpredictable resulting significant impact on water availability. Subsequently, NITI Aayog, GoI has also indicated that special efforts should be made to protect natural springs and streams of the IHR on an urgency basis for long-term sustainable availability of fresh water[10].

However, a sustainable potable water management in the extreme mountainous terrain of Indian Himalaya requires physical and social accounting of water based on availability and demand. This would further be anticipated to address the Sustainable Development Goal number 6 of the United Nation framed in 2015, related to availability and sustainable management of water and sanitation for all. Subsequently, the first step for physical budgeting of water cycle would be to assess distribution of natural water resources that are being used as potable water sources within a state or a region. Numerical quantification of such water sources used for tapped water supply are also anticipated to highlight pressure-scenarios that could be used for identifying water scarce area or region where immediate governmental intervention is solicited. Since, complete water budgeting based on demand and availability of a state or a union territory is extremely non-trivial, source-wise assessment of water supply schemes over the IHR is expected to highlight natural water resources that need immediate attention. Moreover, due to unavailability of such elaborate information or assessment of source wise distribution of water supply schemes over the Indian Himalayas, this report is aimed to highlight the current situation of natural water sources used for tapped water supply for the state of Uttarakhand. Therefore, this report would be providing a prioritized list of natural water resources harvested for maximum benefit to the society as well as under maximum usage threats. Moreover, the report is expected to shed light on freshwater vulnerability through an integrated index based approach wherein hydrological, environmental and demographic factors are integrated. Therefore, the current report is organized such that a brief description of the Uttarakhand state would be provided with an emphasis to water resources. The methodology section would briefly describe the data and analysis method for assessing natural source wise distribution of water supply schemes in every block of the Uttarakhand, along with a brief description of integrated index based approach for water scarcity. Finally, status of water resource availability and vulnerability would be described in the results section, and a summary of the assessment with few recommendations would be made at the end.

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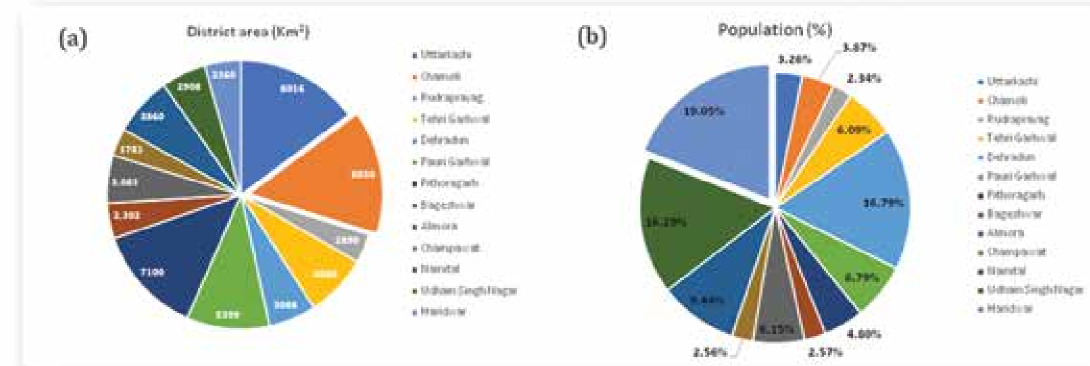
2 State at a glance

The state of Uttarakhand was established as 27th state of India in November 2000, and had given special category status by Union of India due to its strategic and geographic location. The topography of Uttarakhand is characterized by hilly and rugged terrain, deep valleys, high peaks, sharp stream and rivulets, rapid soil erosion, frequent landslides and widely scattered population. The state shares its international boundary with China in north-east and Nepal at its south-east while within the country its neighbouring states are Himachal Pradesh and Uttar Pradesh. Geographically it extends from 28°43' to 31°27' N (latitude) and 77°34' to 81°02' E (longitude) with the total area of 53483 km² including 86.07% hilly area and 13.93% plain area. The Uttarakhand state consists of 13 districts which are grouped administratively into two divisions — Kumaun and Garhwal. There are 6 districts in Kumaun division and 7 districts in Garhwal division. Under 13 districts there are 110 tehsils and 18 sub tehsils and 95 developmental blocks **(Table 1)**. The state geographically consists of three zones i.e upper hills, middle hills and foothills. Upper hills include Uttarkashi, Chamoli, Rudraprayag, Pithoragarh and Bageshwar, middle hills include Tehri-Garhwal, Pauri-Garhwal, Almora, and Champawat, the hill regions of Nainital and Chakrata tehsil of Dehradun and foothills includes Nainital. Among all the districts of Uttarakhand, Chamoli is having highest geographical area **(Figure – 1a)**. District-wise population of Uttarakhand is provided in **Figure – 1b**. According to census 2011, the state has total population of 10,086,292. Maximum population was noted in Haridwar and lowest population was noted in Rudraprayag.

Table 1: Developmental blocks of Uttarakhand

Name of the Districts	Name of the blocks
Almora	(i) Bhaisachhana, (ii)Bhikiasain, (iii) Chaukhutia, (iv) Dwarahat, (v) Dhauladevi, (vi) Hawalbag, (vii) Lamgarha, (viii) Sult, (ix) Syaldeh (x) Takula, (xi) Tariket
Bageshwar	(i) Bageshwar, (ii) Garur, (iii) Kapkote
Chamoli	(i) Dasoli, (ii) Deval, (iii) Gairsain, (iv) Ghaat, (v) Joshimath, (vi) Karnprayag, (vii) Naryanbagar, (viii) Pokhari, (ix) Tharali
Champawat	(i) Barakote, (ii) Champawat, (iii) Lohaghat, (iv) Pati
Pauri-Garhwal	(i) Bironkhal, (ii) Dugadda, (iii) Dwarikhal, (iv) Ekeshwar, (v) Jairikhal, (vi)Kaljikhal, (vii) Khirsu, (viii) Kot, (ix) Nainidanda, (x) Pabau, (xi) Pauri, (xii) Pokhra, (xiii) Rikhnikhal, (xiv) Thalisain, (xv) Yamkeshwar
Haridwar	(i) Bahadrabad, (ii) Bhagwanpur, (iii) Khanpur, (iv) Laksar, (v) Narsan, (vi) Roorkee
Nainital	(i) Betalghat, (ii) Bhimtal, (iii) Dhari, (iv) Haldwani, (v) Kotabagh, (vi) Okhalkanda, (vii) Ramgarh, (viii) Ramnagar
Pithoragarh	(i) Berinag, (ii) Bin, (iii) Dharchula, (iv) Didihat, (v) Gangolihat, (vi) Kanalichhina, (vii) Munakote, (viii) Munsiyari
Rudraprayag	(i) Augustmuni, (ii) Jakholi, (iii) Ukhimath
Tehri-Garhwal	(i) Jakhanidhar, (ii) Bhilangana, (iii) Chamba, (iv) Devprayag, (v) Jaunpur, (vi) Kirtinagar, (vii) Narendra Nagar (viii) Partapnagar, (ix) Thauldhar
Udham Singh Nagar	(i) Bazpur, (ii) Gadarpur, (iii) Jashpur, (iv) Kashipur, (v) Khatima, (vi) Rudrapur, (vii) Sitarganj
Uttarkasi	(i) Bhatwali, (ii) Chinyalisaur, (iii) Dunda, (iv) mori, (v) Naugaon, (vi) Purola
Dehradun	(i)Chakrata, (ii) Doiwala, (iii) Kalsi, (iv) Raipur, (v) Sahaspur, (vi) Vikasnagar

Figure 1: Subplot (a) and (b) indicates district-wise distribution of area and population in Uttarakhand. Source: Uttarakhand Census Handbook, 2018.



The state is fed with different glacier fed and perennial rivers and their tributaries along with other ground water sources **(Table 2)**. Due to the availability of water through glacier fed rivers in many districts of the state, various hydropower projects are running on the rivers Yamuna, Bhagirathi, Bhilangana, Alaknanda, Mandakini, Saryu, Gauri, Kosi and Kali, through which approximately 25,450 MW are being produced (https://knowindia.gov.in/states-uts/uttarakhand.php). State receives an average rainfall of 1631 mm. and temperature generally ranges from -3.4

Table 2: Major water resources of Uttarakhand.

S.No.	District	Drainage	Major rivers/ tributaries
1	Almora	River	Kosi, Ramganga, Suyal, Gagas
2	Bageshwar	River	Saryu, Gomti and Pindar
3	Chamoli	River	Alaknanda, Ramganga, Dhauliganga, Nandakini, Pindar
4	Champawat	River	Sarju, Kali/Sarda
5	Dehradun	River	Asan, Song, Tons, Rispina
6	Haridwar	River	Ganga, Solani
7	Nainital	River	Kosi, Gola, Nandhaur, Dabka, Baur and Bhakra
		Other water sources	Nainital, Bhimtal, Malwa Tal, Sat Tal, Naukuchhiya Tal, Khurpa Tal, Sariya Tal and the Khuriya Tal
8	Pauri Garhwal	River	Ganga, Alakhnanda, Nayar
9	Pithoragarh	River	Goriganga , Kali river, Saryu, Ramganga, Yangti, Dhauli and Kuti
10	Rudraprayag	River	Mandakini, Alaknanda
11	Tehri garhwal	River	Bhagirathi, Bhilangana, Alaknandaa, Ganga
12	Udham Singh Nagar	River	Sarada, Gola, Phikka
13	Uttarkashi	River	Bhagirathi, Yamuna, Tons

3 Method

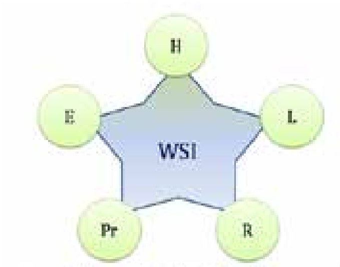
3.1 Data and analysis for assessing source wise distribution of water supply schemes

In order to assess source wise distribution of water supply schemes in every block of the Uttarakhand state, water supply data was downloaded from the Ministry of Jalshakti, GOI, IMIS web server updated till 31st July, 2019. Total number of water schemes harvesting natural resources was compiled for each block. In order to have a simplified visual comparison, pie charts are produced on percent distribution of fresh water resources harvested for water supply. The generic color code for the following sources is kept similar so that easy visual comparison could be made: (i) Deep tube well, (ii) Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis, (iii) Infiltration well, (iv) River, (v) Rivulet / Naula / Gadhera, and (vi) Spring. The terminology 'Naula' cannot be considered synonymous to 'Spring', rather it represents a form of surface flowing water. Consequently, in spite of two different categories representing different form of ground water, these two categories could be conjectured to be generic forms of ground water out-flow in the hilly terrains of Himalaya. The standard color codes used for these individual classes in the pie chart are provided in Figure 2. This is also to be noted that instead of using the larger nomenclature of 'Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis', the pie charts include the smaller nomenclature 'Ponds / Wells/ Ooranis'.

Figure 2: Standard color code used for preparing pie chart on percent distribution of dominant natural water resources harvested for water supply within Uttarakhand.

3.2 Data and analysis for integrated index based approach for water vulnerability

The integrated index based approach for assessing fresh water vulnerability within Uttarakhand was adopted using the generic water sustainability framework of Chavez and Alipaz (2007)[11]. The index used for estimating vulnerability was 'Water Sustainability Index' (WSI). The range of WSI can vary between 0-1, where a value of 0 indicates highest water scarcity and 1 indicates lowest water scarcity. The five components of WSI were Hydrology (H), Environment (E), Life (L), Rainfall (R) and Vertical Proximity (Pr$_i$) as indicated in **Box-1**.



Box – 1: Water sustainability index (WSI) computed using individual indices of Hydrology (H), Environment (E), Life (L), Vertical Proximity (Pr) and Rainfall (R)

The WSI was estimated at a block level. Digital and geo-referenced Uttarakhand administrative block boundary was prepared at GBPNIHESD, Almora. The digital imagery was co-registered using exiting ground control point (GCPs) to remove the geo-referencing errors. The boundary was projected using <WGS_1984_UTM_ZONE_44N>. All the ninety five blocks of Uttarakhand were mapped and depicted in the block boundary.

The block level Hydrology index map was prepared, first, by using high resolution Digital Elevation Model (DEM) data of Alos Palsar at 12.5 m, mosaiced and clipped along the state boundary. Subsequently, 'Fill', 'Flow direction', 'Flow accumulation', 'Pour points', etc. maps were prepared to derive the 'Drainage and watershed boundary' of the Uttarakhand state. Elevation profile of the block zone was geospatially analyzed to prepare the average elevation map at block level for the state. Next, four further major components of hydrology indices were geospatially mapped: (i) Demography and water demand, (ii) Cattle distribution

[11]Chavez and Alipaz (2006): An integrated indicator for basin hydrology, environment, life and policy: The Water Sustainability Index.

and water demand, (iii) Water availability from major rivers, and (iv) Block-wise total Water availability and Demand.

The Demography data was integrated geospatially with the block boundary of the state to prepare the water demand map. The census 2011 demography data from the www.censusindia.gov.in website of Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India was downloaded and compiled at block level to categorize the rural, urban and total population of the Uttarakhand state. The standard per capita water demand in Litres per day [Litre Per Capita Demand (lpcd)] was taken to be 40 lpcd for rural population and 135 lpcd for urban population (as per the standards laid down by the World Health Organization or the Bureau of Indian Standards, 1993). Finally, block-wise Demography and water demand was prepared.

The cattle census data was integrated geospatially with the block boundary of the state to prepare the water demand map **(Table 3)**. The cattle distribution was then linearly interpolated to each block as a function of demography. A report on Livestock Water Requirement by NDSU Extension Service, July 2015, suggests the water demand of different livestock. The reported figures were utilized to derive the water demand by the different categories of cattle at block level as 20 litres for cow, 30 litres for buffalo, 3 litres for goat and sheep and 7 litres for pig. The total water demand by human population and cattle was compiled at the block level.

Table 3: District-wise cattle census data of Uttarakhand, 2012. (Source: Statistics and Census – Animal Husbandry, Govt. of Uttarakhand).

S. No.	District	Cattle Census 2012				
		Cow	Buffalo	Sheep	Goat	Pig
1.	Almora	838348	410988	158072	803911	4516
2.	Bageshwar	428886	149646	746979	452699	251
3.	Chamoli	604572	165004	3910960	311748	1328
4.	Champawat	378166	95570	0	210346	1143
5.	Dehradun	435527	127639	284602	329448	10349
6.	Garhwal	1227034	156416	1030922	725793	2962
7.	Hardwar	620411	964631	231294	99320	38095
8.	Nainital	556800	285703	11685	222603	2921
9.	Pithoragarh	746411	188153	1749207	743103	827
10.	Rudraprayag	405699	141042	666870	160328	232
11.	Tehri Garhwal	444232	404670	1921615	557834	2826
12.	Udham Singh Nagar	267617	318005	33592	82860	3359
13.	Uttarkashi	497102	138825	4216274	542266	909

To prepare the geospatial water availability at block level from major rivers, the annual average discharge in cubic metre per second of important rivers of Uttarakhand **(Table 4)** was availed from different published reports. The daily discharge was calculated in litres water per day using the formula:

$$\textit{Water discharge (l/day)} = Q * 86400 * 1000$$

where, Q is the annual average discharge of the river in cubic metre per second. The total daily water availability at block level was computed, first by estimating proportionate block area with respect to total watershed area of a particular river. Finally the daily water availability at block level was estimated by considering 2 % of total daily water availability at block level. This is the effective daily water availability at block level. The 2% usages of total daily water availability at block was considered for household use to ensure the sufficient water flow at downstream and also for other water demand such as ground infiltration, irrigation, etc.

To prepare the geospatial Block-wise total Water availability and Demand, a ratio of total water availability and total water demand at block level was calculated. This ratio was finally used to produce Hydrological Index. The criterion for developing Hydrological Index was the per-capita water availability within a block spatial scale. The hypothesis for H index was 'higher the water availability, higher is the index'. A normalized H index was categorized in to four classes: H = 0.25 (for availability and demand ratio less than 2.0) indicating poor index; H = 0.50 (for availability and demand ratio within 2.0-6.0) moderate index; H = 0.75 (for availability and demand ratio within 6.0 - 10.0) good index and H = 1.0 (for availability and demand ratio more than 10.0) excellent index.

The criterion for developing Environment Index (E) was the percentage vegetation cover within a block spatial scale. To estimate block-wise vegetation cover, bands of Landsat 8 data at 30m for Uttarakhand State were downloaded and

Table 4: Major rivers and mean annual discharges considered for indexing.

River Name	Annual Average Discharge (m^3/Sec)
Kosi River	8.900
Kali River	420.700
Ramganga River	20.101
Ganga	656.000
Gagas River	15.186
Saryu River	195.500
Nayar	32.670
Ramganga	4.920
Pinder River	94.260
Alaknanda	287.000
Dhauliganga River	72.600
Mandakani River	105.000
Bhagirathi	246.440
Goriganga River	169.000
Yamuna River	220.000
Tons River	5.740

Blue (B2), Green (B3), Red (B4) and Infrared (B5) were integrated to form the composite layers. The satellite imagery was classified for the extraction of vegetation using the object based classification method. Normalized Difference Water Index (NDVI) was utilized to extract the vegetation cover in the state using the threshold value (greater than 0.23). The accuracy assessment of the classification was performed using the existing ground GPS point and Google Earth Engine - High Resolution Imagery. The accuracy of the classification was found to be greater than 85%. Based on the vegetation cover derived from the 30 m Landsat satellite imagery, the Environmental Index at block level was calculated for four classes: E = 0.25 (for less than 25% vegetation cover in the block) indicating poor index; E = 0.50 (for 25-50% vegetation cover in the block) moderate index; E = 0.75 (for 50-75% vegetation cover in the block) good index and E = 1.0 (for more than 75% vegetation cover in the block) excellent index. The hypothesis for E index was 'Higher the vegetation cover, higher is the index'.

Similarly, the criterion for developing Life Index (L) was the population distribution within a block spatial scale. The hypothesis for L index was 'Higher the population distribution, lower is the index'. Population density at the block scale was estimated using the Census – 2011 data of GoI. Total population was summation of urban and rural population. The population density was calculated for each block and geospatially integrated with the block boundary. The Life index has been calculated in four classes: L = 0.25 (less than 100) indicating poor index; L = 0.50 (100 - 250) moderate index; L = 0.75 (250 - 400) good index and L = 1.0 (more than 400) excellent index.

The criterion for developing Rain Index (R) was the mean annual rainfall data obtained at 25 Km grid from APHRODITE (Japan). There were scenarios where a block was completely lying under the single grid and also four square grids covering the single block. In later case, the average rainfall was calculated by taking the proportionate average of individual grids within the block. Based on the mean value of annual rainfall, R index was calculated as R = 0.25 (for rainfall less than 1032 mm) indicating poor index; R = 0.50 (for rainfall within 1032 – 1282mm) moderate index; R = 0.75 (for rainfall within 1282 – 1532 mm) good index and R = 1.0 (for rainfall more than 1532 mm) excellent index.

The criterion for developing Vertical Proximity (Pri) index was the mean elevation of individual block. The mean elevation of each block was computed using the available DEM data over the GIS platform to calculate the vertical proximity. This index is useful because the blocks lying at lower elevations were mostly drained by higher order streams and also due to availability of the groundwater extracted through wells. The Pri index is calculated as Pr_i = 0.25 (for elevation less than 1000 m) indicating poor index; Pri = 0.50 (for elevation within 1000-1500 m) moderate index; Pri = 0.75 (for elevation within 1500-2000 m) good index and Pri = 1.0 (for elevation more than 2000 m) excellent index.

Once the indices of H, L, E, R and Pri were computed, a cumulative WSI was estimated at block level as:

$$WSI=((0.4*Pri)+(0.3*Hi)+0.1*(Ei+Li+Ri))$$

Finally, Water Scarcity Index was computed as:

$$\text{Water Scarcity Index} = (1-WSI)$$

Therefore, a value of Water Scarcity Index 0(1) will be representing lowest (highest) scarcity.

4 Results: water availability and vulnerability

The results section is broadly categorized in to two parts. The first part highlights block and district-wise distribution of natural water resources that are being harvested for fresh water supply. The second part highlights blocks and districts that are highly vulnerable as per the integrated index based estimationof water vulnerability.

4.1 Distribution of water sources harvested for water supply

As indicated in the **Table 1**, there are 13 districts in Uttarakhand of which Pauri-Garhwal is having a maximum total of 15 numbers of Blocks. Brief descriptions of block-wise distributions of water sources in each district used for water supply schemes are provided below.

4.1.1 Almora

- The common generic water sources used for water supply schemes over the districts are:
  - i. *Deep Tube-well,*
  - ii. *Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - iii. *Infiltration well,*
  - iv. *River,*
  - v. *Rivulet / Naula / Gadhera,*
  - vi. *Spring,*
  - vii. *Treated Surface Water,*
  - viii. *Streams*
- Block-wise distribution of water sources in the Almora district of Uttarakhand used for water supply by governmental agenciesis provided in **Annexure 1**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from Lake, roof-top rain water structure, open-well and shallow tube-well.
- The total number of operational water schemes in Almora district is noted to be 9034.
- Rivulet / Naula / Gadherais noted to be highly tapped for water schemes in Almora. An average of 60.8% water supply schemes is found to be dependent on Rivulet / Naula / Gadhera of Almora District and the water is largely contributed by the springs during dry season.
- The average dependency of water supply schemes directly on Springs over Almora district is noted to be 2.8%. The Sult block of Almora has the highest water dependency on Springs.
- Water supply schemes based on Treated Surface Water is noted to be more than 50% of all the schemes in Syaldey and Sult block of Almora.

4.1.2 Bageshwar

- The common generic water sources used for water supply schemes over the districts are:
  - i. *Deep Tube-well,*
  - ii. *Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - iii. *River,*
  - iv. *Rivulet / Naula / Gadhera,*
  - v. *Spring,*
  - vi. *Treated Surface Water,*
  - vii. *Streams*
- Block-wise distribution of water sources in the Bageshwar district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 2**.
- The total number of operational water schemes in Bageshwar district is noted to be 1320.
- Rivulet / Naula / Gadhera (30.3%) followed by Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis(25.6%)and Treated surface water (24.2%)are noted to be highly tapped for water schemes in Bageshwar.
- The average dependency of water supply schemes directly on Springs over Bageshwar district is noted to be 8.6%. The Garur block of Bageshwar has the highest water dependency on Springs.

4.1.3 Chamoli

- The common generic water sources used for water supply schemes over the districts are:
  - i. *Deep Tube-well,*
  - ii. *Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - iii. *Rivulet / Naula / Gadhera,*
  - iv. *Spring,*
  - v. *Streams,*
  - vi. *Treated surface water*
- Block-wise distribution of water sources in the Chamoli district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 3**.
- The total number of operational water schemes in Chamoli district is noted to be 1805.

- Springs(70.3%)followed by Streams(20.4%) and Rivulet / Naula / Gadhera (7.3%) are noted to be highly tapped for water schemes in Chamoli
- The Ghaat block of Chamoli district has the highest water dependency on Springs (84%).

4.1.4 Champawat

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Deep Tube-well,*
  - *ii. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - *iii. Infiltration well,*
  - *iv. River,*
  - *v. Rivulet / Naula / Gadhera,*
  - *vi. Spring,*
  - *vii. Treated Surface Water,*
  - *viii. Streams*
- Block-wise distribution of water sources in the Champawat district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 4**.
- The total number of operational water schemes in Champawat district is noted to be 1501.
- Rivulet / Naula / Gadhera (79.5%) followed by Springs (8%) and Streams (6%) are noted to be highly tapped for water schemes in Champawat.

The Champawat block has the highest water dependency on Springs, approx. 10% of total water supply schemes is dependent directly on Springs.

4.1.5 Pauri-Garhwal

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Deep Tube-well,*
  - *ii. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - *iii. River,*
  - *iv. Rivulet / Naula / Gadhera,*
  - *v. Spring,*
  - *vi. Treated Surface Water,*
  - *vii. Streams*
- Block-wise distribution of water sources in the Pauri-Gahwal district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 5**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from Infiltration well, Lake, Roof-top rain water structure, open-well and shallow tube-well.
- The total number of operational water schemes in Pauri-Gahwaldistrict is noted to be 5662.
- Rivulet / Naula / Gadhera(45.4%)followed byKhadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis(28.7%)and Springs (15.3%)are noted to be highly tapped for water schemes in Pauri-Garhwal.
- The Rikhnikhal block has the highest water dependency directly on Springs, approx.87% of total water supply schemes is dependent on Springs.

4.1.6 Haridwar

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Deep Tube-well,*
  - *ii. Shallow Tube-well,*
  - *iii. Treated surface water*
- Block-wise distribution of water sources in the Haridwar district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 6**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from Infiltration well, Ponds, and open-well.
- The total number of operational water schemes in Haridwardistrict harvesting natural water resources is noted to be 1272.
- Deep Tube-well(72.2%)followed byShallow tube-well(24.8%)andTreated surface water(2.5%)are noted to be highly tapped for water schemes in Haridwar.
- The Khanpur block has the highest water dependency on Deep tube-well, approx.78% of total water supply schemes is dependent on Deep tube-well.
- No block in the Haridwar district is found to directly harvest Springs for water supply, primarily due to unavailability of Springs at lower elevation.

4.1.7 Nainital

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Deep Tube-well,*
  - *ii. Rivulet / Naula / Gadhera*
  - *iii. Spring,*
  - *iv. River,*
  - *v. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,,*
  - *vi. Treated Surface Water,*
  - *vii. Streams*
- Block-wise distribution of water sources in the Nainital district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 7**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from Infiltration well, shallow tube-well and open-well.
- The total number of operational water schemes in Nainital district harvesting natural water resources is noted to be 4095.
- Rivulet / Naula / Gadhera(45.5%)followed byDeep tube-well (24.4%) and Springs(16.6%)are noted to be highly tapped for water schemes in Nainital.
- The Ramgarh block has the highest water dependency on Springs, approx.27% of total water supply schemes in this block is directly dependent on Springs.

4.1.8 Pithoragarh

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Rivulet / Naula / Gadhera*
  - *ii. Spring,*
  - *iii. Stream*
  - *iv. Treated Surface Water,*
  - *v. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
- Block-wise distribution of water sources in the Pithoragarh district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 8**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from Infiltration well, shallow tube-well,open-well and community collection.
- The total number of operational water schemes in Pithoragarh district harvesting natural water resources is noted to be 2053.
- Rivulet / Naula / Gadhera (50.1%) followed bySprings(24.2%) and Streams(18.1%)are noted to be highly tapped for water schemes in Pithoragarh.
- The Didihat block has the highest water dependency on Springs, approx.35% of total water supply schemes in this block is directly dependent on Springs.

4.1.9 Rudraprayag

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Rivulet / Naula / Gadhera*
  - *ii. Spring,*
  - *iii. Deep Tube-well*
  - *iv. Stream*
  - *v. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
- Block-wise distribution of water sources in the Rudraprayag district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 9**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from River and Treated surface water..
- The total number of operational water schemes in Rudraprayag district harvesting natural water resources is noted to be 1925.
- Rivulet / Naula / Gadhera(54.3%)followed bySprings(36%) and Deep tube-well(6%)are noted to be highly tapped for water schemes in Rudraprayag.
- The Augustmuni block has the highest water dependency on Springs, approx.39% of total water supply schemes in this block is directly dependent on Springs.

4.1.10 Tehri-Garhwal

- The common generic water sources used for water supply schemes over the districts are:
  - *i. Rivulet / Naula / Gadhera*
  - *ii. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,*
  - *iii. Spring,*
  - *iv. Stream*
  - *v. Deep tube-well*
- Block-wise distribution of water sources in the Tehri-Garhwal district of Uttarakhand used for water supply by the governmental agencies is provided in **Annexure 10**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from River, Treated surface water, shallow tube-well, canal and community collection.
- The total number of operational water schemes in Tehri-Garhwal district harvesting natural water resources is noted to be 5161.
- Rivulet / Naula / Gadhera(53.4%)followed bySprings(20.1%) and Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis(15.6%)are noted to be highly tapped for water schemes in Tehri-Garhwal.
- The Jakhanidhar block has the highest water dependency on Springs, approx.45% of total water supply schemes in this block is dependent on Springs.

4.1.11 Udham Singh Nagar

- The only two dominant water sources used for water supply schemes over the districts are:
  - *i. Deep Tube-well, and*
  - *ii. Shallow Tube-well,*
- Block-wise distribution of water sources in the Udham Singh Nagar district of Uttarakhand used for water supply by governmental agencies is provided in **Annexure 11**.
- Other than the above mentioned generic water sources, only a single cases is identified wherein water supply scheme is operational through an Open Well.
- The total number of operational water schemes in Udham Singh Nagar district harvesting natural water resources is noted to be 3008.
- Deep Tube-well (81.3%)followed by Shallow tube-well (18.7%)noted to be tapped for all the water schemes in Udhamsingh Nagarexcept for a single case using Open well.
- The Khatima block has the highest water dependency

on Deep tube-well, approx.92.5% of total water supply schemes is dependent on Deep tube-well.
- No block in the Udham Singh Nagar district is found to harvest Springs for water supply, primarily due to unavailability of Springs at lower elevation alike Haridwar District.

4.1.12 Uttarkashi

- The common generic water sources used for water supply schemes over the districts are:
  vi. Rivulet / Naula / Gadhera
  vii. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,
  viii. Spring,
  ix. Stream,
  x. Deep tube-well

- Block-wise distribution of water sources in the Uttarkashi district of Uttarakhand used for water supply by the governmental agencies is provided in **Annexure 12**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from River, Treated surface water, and Open well.
- The total number of operational water schemes in Uttarkashi district harvesting natural water resources is noted to be 3581.
- Rivulet / Naula / Gadhera (69.2%) followed bySprings(13.3%) andDeep Tube Well (9.7%) are noted to be highly tapped for water schemes in Uttarkashi.
- The Purola block has the highest water dependency on Springs, approx.21% of total water supply schemes in this block is directly dependent on Springs.

4.1.13 Dehradun

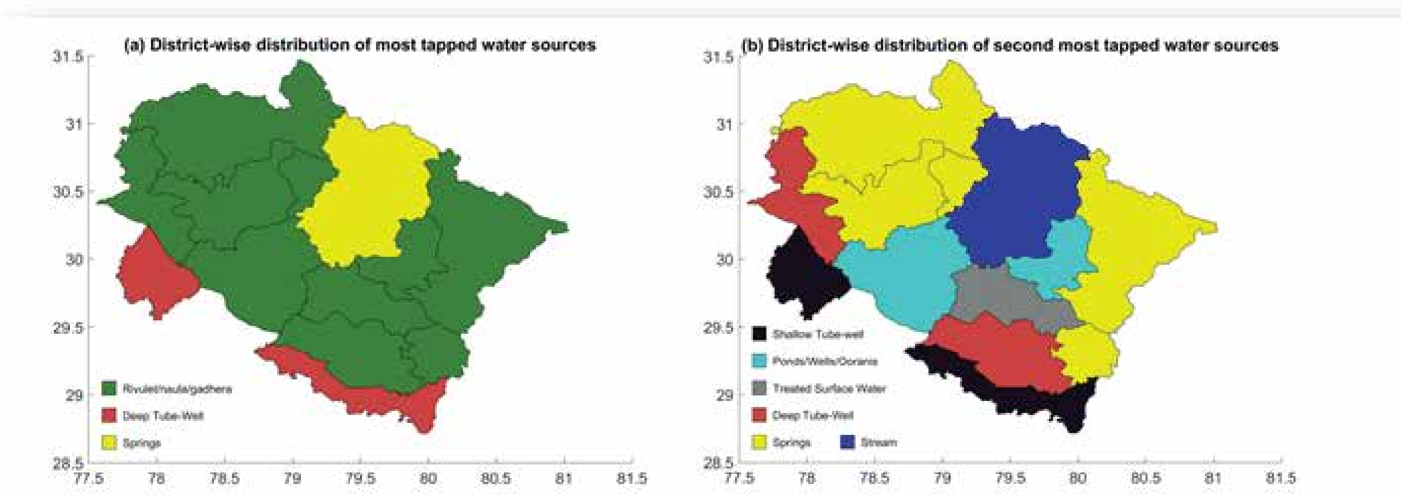
- The common generic water sources used for water supply schemes over the districts are:
  i. Deep tube-well
  ii. Rivulet / Naula / Gadhera
  iii. Spring,
  iv. Khadins / Nadins/ Tankas/ Ponds / Wells/ Ooranis,
  v. Stream,

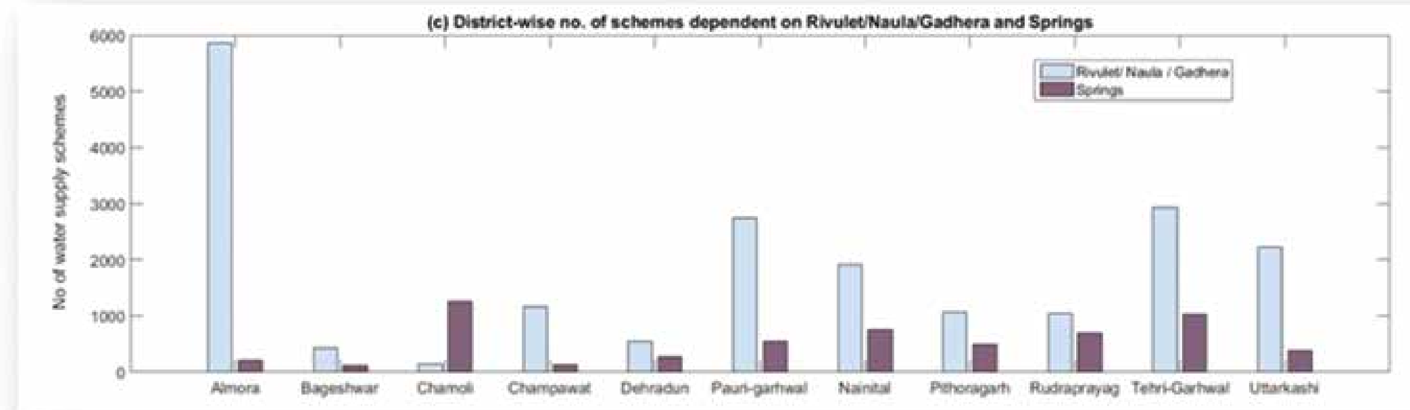
- Block-wise distribution of water sources in the Dehradun district of Uttarakhand used for water supply by the governmental agencies is provided in **Annexure 13**.
- Other than the above mentioned generic water sources, few cases are also identified wherein water supply schemes are operational through water from River, Treated surface water, Shallow well, Open well, and Canal.
- The total number of operational water schemes in Dehradun district harvesting natural water resources is noted to be 1336.
- Rivulet / Naula / Gadhera(36.7%)followed by Deep Tube Well (29.3%) and Springs(18.8%) are noted to be highly tapped for water schemes in Dehradun.
- The Chakrata block has the highest water dependency on Springs, approx.27% of total water supply schemes in this block is directly dependent on Springs.

4.2 Spatial characteristics of fresh water sources harvested for water supply schemes:

For the entire state of Uttarkhand, a total of 41753 fresh water supply schemes were documented till 31st July, 2019 harvesting different water resources. The block-wise assessment of source wise distribution of water supply schemes indicates that except for the four low lying districts (i.e. Udham Singh Nagar, Dehradun, Haridwar and partly Nainital), most of the districts in Uttarakhand are highly dependent of natural Rivulets, Naula, Gadhera(a total of 20,051 schemes out of 41,753) and Springs(a total of 5,866 schemes out of 41,753) (Figure 3). Amongst the total of 95 blocks within Uttarakhand, a total of 54 blocks (56.8%) was found to be most dependent on Rivulet / Naula / Gadherafor piped fresh water supply. Similarly, a total of 10 blocks (10.5%) was found to be most dependent on Springs. Subsequently, any natural and / anthropogenically induced change to these very fragile water resources are anticipated to have significant impact on fresh water availability.

Figure 3: Subplot (a) and (b) indicates district-wise distribution of most tapped and second most tapped water resources in Uttarakhand. Subplot (c) indicates district-wise comparison of total number of schemes harvesting fresh water from Rivulet / Naula / GadheraandSprings.





Moreover, concentration of fresh water supply schemes per 100,000 population was estimated for each district of the state, and Pithoragarh district followed by Chamoli (Nainital is not considered as purely hill district) were noted to have lowest concetration of schemes (425.0 and 462 schemes, respectively) per 100,000 population amongst the hilly districts of Uttarakhand **(Figure 4)**. The hypothesis for this estimation of concentration of water scheme is *"increased tapping of mountain specific water resources would benefit more population under standardmanagement practise"*. However, one can note that concentration of freshwater schemes harvesting natural water resources are also poor for Dehradun, Haridwar and Udham Singh Nagar districts. Since these low lying districts are highly dependent on deep tube-well directly harvesting ground water, unlike hilly districts a small number of deep tube-well schemes are presumed to be sufficient to support a rather larger population. Therefore, the above mentioned mountain specific hypothesis is not applicable for low lying districts of the state.

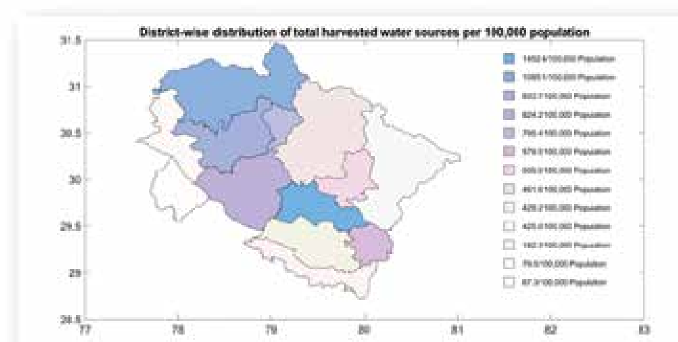


Figure 4: District-wise distribution of total harvested water sources per 100,000 populations in Uttarakhand.

4.3 Water vulnerability

The block-wise distribution of five components of WSI, i.e. Hydrology (H), Environment (E), Life (L), Rainfall (R) and Vertical Proximity (Pri), are provided in Figure 5. It can be noted from the L index that most of the mid-Himalayan hilly districts are having moderate population load where as E, R and Pri indices are having maximum vulnerability for higher mountain districts. However, due to availability of significant surface water through rivers and less population density, the higher mountainous districts were noted to have high H indices. The final Water Scarcity Indices for all the districts of Uttarakhand indicates that the low lying districts of Kumaun regions are having much lesser water scarcity than some of the mid Himalayan districts where population load along with unavailability of surface water resulting maximum water scarcity.

The Water Scarcity Indices for all the blocks of Uttarakhand further indicated that Ghaat block of Champawat, Ramgarh block of Nainital, Garur block of Bageshwar and Pokhra block of Pauri-Garhwal were amongst the most water scarce blocks. The highest water scarce blocks of each district of Uttarakhand is provided in **Table 5**. Surprisingly, fresh water supply schemes in all these blocks were also noted to be highly dependent on Springs. Consequently, these blocks can be categorized as extremely vulnerable having maximum water resource threat on Springs.

Figure 5: Block-wise distribution of five components of WSI, i.e. Hydrology (H), Environment (E), Life (L), Rainfall (R) and Vertical Proximity (Pri). CONTD.....

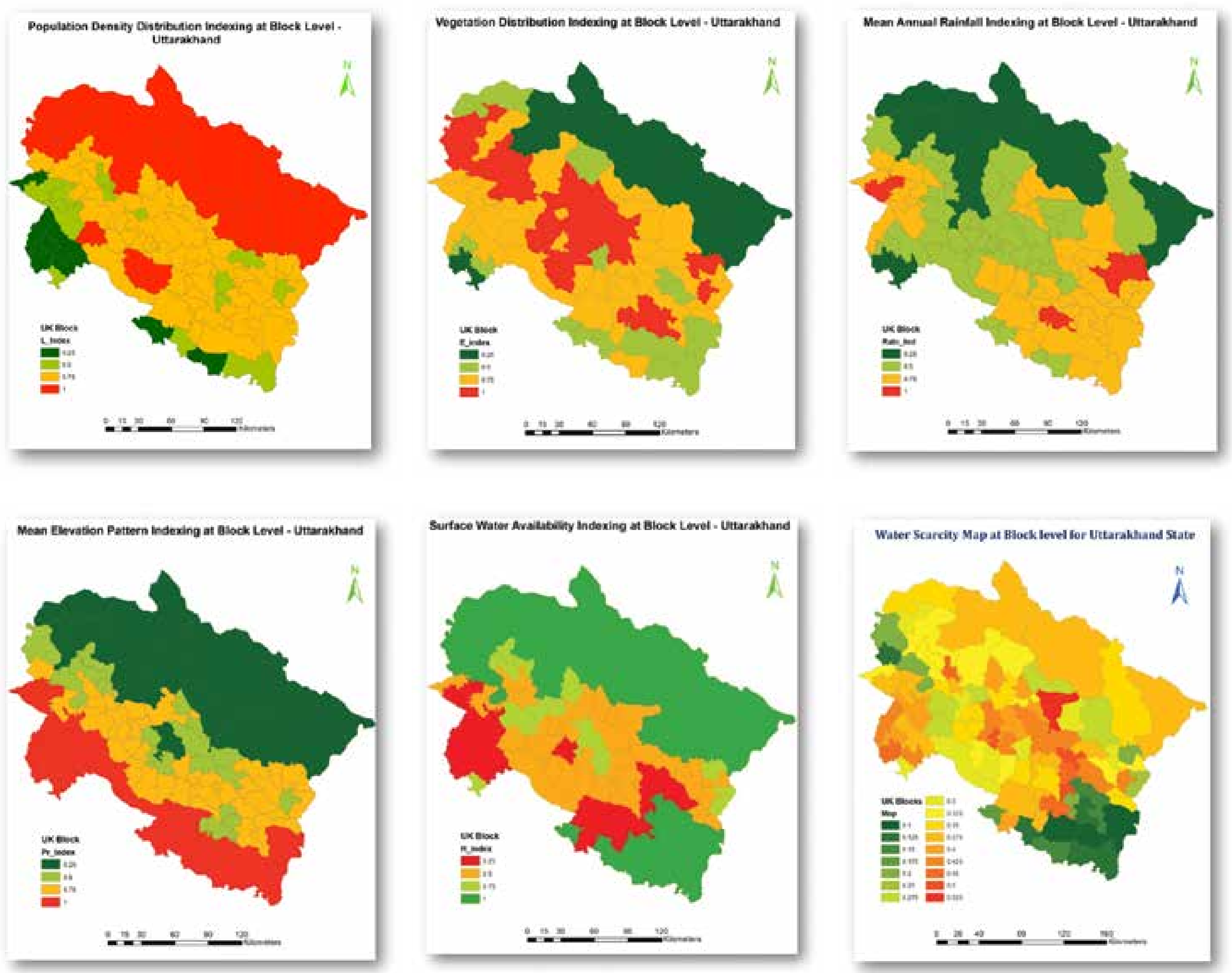


Table 3: Highest water scarce block in each district of Uttarakhand as estimated using integrated index based approach.

S. No.	District	Highest Water Scarce Block	Water Scarcity Index
1.	Almora	Takula	0.50
2.	Bageshwar	Garud	0.425
3.	Chamoli	Ghaat, Tharali	0.52, 0.52
4.	Champawat	Barakote, Lohaghat	0.35, 0.35
5.	Dehradun	Doiwala	0.40
6.	Pauri-Garhwal	Pokhara	0.52
7.	Hardwar	Narsan	0.45
8.	Nainital	Ramgarh	0.50
9.	Pithoragarh	Pithoragarh	0.425
10.	Rudraprayag	Jakholi	0.40
11.	Tehri Garhwal	Partapnagar	0.45
12.	Udham Singh Nagar	Kashipur	0.40
13.	Uttarkashi	Bhatwari	0.375

6 Summary and recommendation

This report is aimed at highlighting two broad issues of fresh water in the Himalayan state of Uttarakhand, (i) the current situation of natural water sources used for tapped water supply for the state; and (ii) fresh water vulnerability through an integrated index based approach wherein hydrological, environmental and demographic factors are coalesced. The generic findings related to the current situation of natural water sources used for tapped water supply and water scarcity amongsts blocks are :

- Supply of fresh water in the hilly districts of Uttarakhand are mostly dependent on Rivulet/Naula/Gadheraand Springs as 48.02% and 14.04% of total water supply schemes of the state are dependent on these two fragile sources. These Rivulet/Naula/Gadhera are largely dependent on the baseflow generated by the springs and other groundwater sources during crtical dry months.
- Around 56.8% of the all the administrative blocks of Uttarakhand are to be most dependent on Rivulet / Naula / Gadherafor piped fresh water supply.
- More than 90% of all the water supply schemes in low lying states of Uttarakhand are dependent on some form of well, either deep or shallow.
- In terms of concentration of water supply schemes per 100,000 populations over mountain districts, it is noted that Pithoragarh followed by Chamoli are having lowest concentrations of water supply schemes. However, this is to be noted that these estimates do not include quantitative water availability.
- Water supply schemes through harvested rain water stored in ponds or similar structures are barely implemented.
- The integrated index based assessmenr of water scaricyt for Uttarakhand indicates that Ghaat, Tharali and Pokhra are the highest water scarce blocks. These blocks are further noted to be highly dependent on Springs.
- The median water scarcity index of all the blocks with 25th and 75th percentile range are noted to be 0.35, 0.3 and 0.4, respectively. The total number of water scarce blocks (water scarcity index greater than 0.4) are noted to be 21 **(Annexure 14)**.
- The maximum numbers of water scarce blocks are noted for Pauri-Garhwal (6 blocks) and Almora (5 blocks).

The major issues realized during the composition of this report related to water availability from the natural water sources used for tapped water supply are:

- Unavailbility of source-wise discharge and/ extraction data
- Unavailability of current status of schemes, i.e. functional, non-functional, etc.
- Unavailability of total number of population benefitted from each scheme.

Therefore, some of the generic recommendations for sustainable usages of natural water sources of Uttarakhand should include:

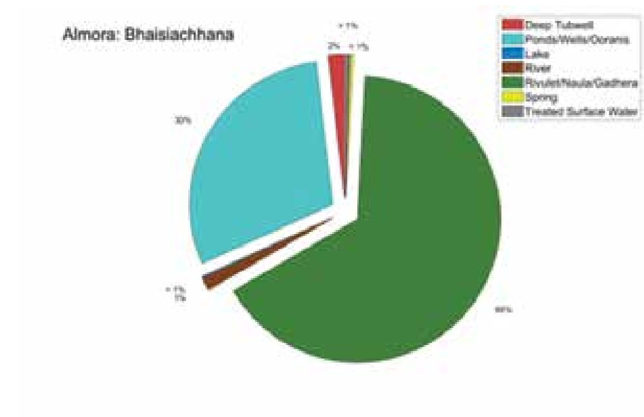
- The majority of sources used for water supply in the state are either springs or spring fed rivulets and majority of these sources are showing decline in their flow. Considering this, the source centred approach of spring rejuvenation incorporating integrated bio-physical and social measures for rain water harvesting, can provide viable solutions to water sustainability of the region. One of the viable options could be development of dedicated Water Sanctuaries (Jal Abhyaranya) in each villages for rejuvenating at least one perennial spring/ stream based on spring sanctuary concept. Launching a mass movement for creation of well protected spring catchment with appropriate policy backup and active participation of villagers can help in achieving the water security in mountain villages within a specific time frame.
- Now several ministries and developmental agencies have accepted the concept of watershed for wasteland restorations, recharging of water sources, creating and empowering of decentralized village institutions, and strengthening of the participatory processes.The need of the hour is to dovetail water source centered approach into all watershed development projects which are presently focused on an area based planning for livelihood improvement.
- Monitoring and evaluation of any catchment intervention through quantitative indicators like water discharge pattern, water quality index, biomass yield, etc. need to be included in pre & post project stages.
- Providing equitable access to water, both in terms of quality and quantity, is one of the major challenges on

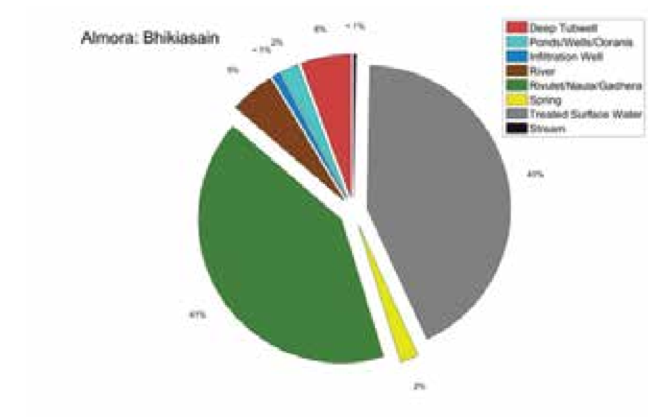
the way to sustainable management of water. Apart from inter and intra state conflicts on sharing water, agricultural, industrial and domestic uses are competing increasingly because of limited supply. Optimisation of water allocation is needed for its efficient utilisation as water requirement is closely related to population, demand for food, production of non-agricultural and industrial items, production of energy and improvement of the quality of life, and preserving the ecology of the region.

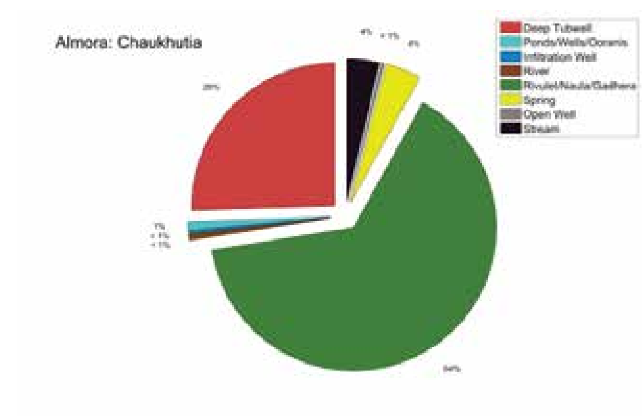
- Information sharing mechanism for water data is urgently needed. A continuous monitoring of hydro-meteorological data and consequent assessment about the ups and downs in precipitation amount and temperature rise would further help the planners in strengthening their planning and making projections for water management for future. There is also lack of well-developed meteorological and river gauging network for improving the knowledge on surface and subsurface hydrology, rainfall and sediment transport, etc. throughout the state.
- Data of Natural Springs is hardly available in the state. There is a need for launching a time bound campaign in the state for creating a GIS based inventory of the natural springs of Uttarakhand state, which will help in developing better understanding of the springs and preparation of village Spring Atlas for planning purposes.

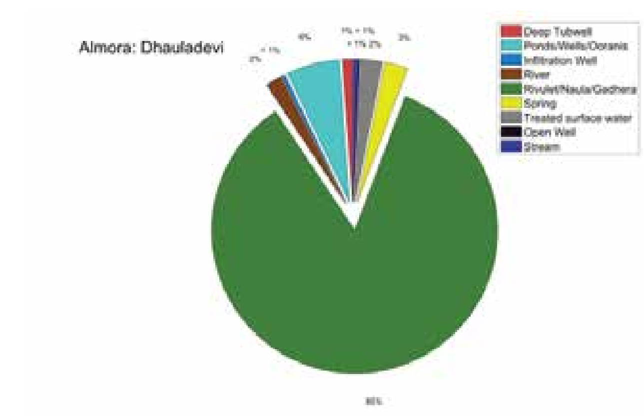
ANNEXURES

Annexure 1: *Block-wise distribution of water sources in the Almora district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*









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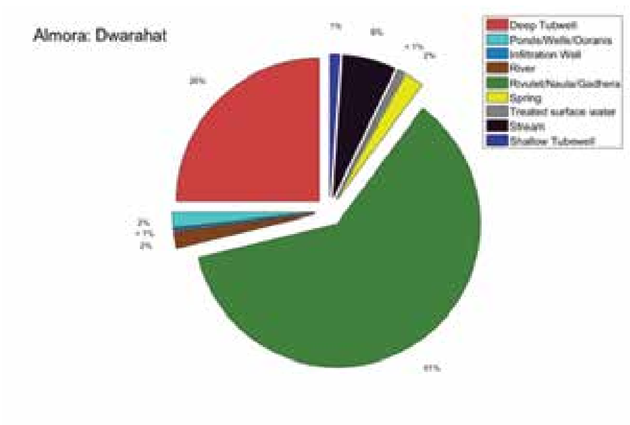

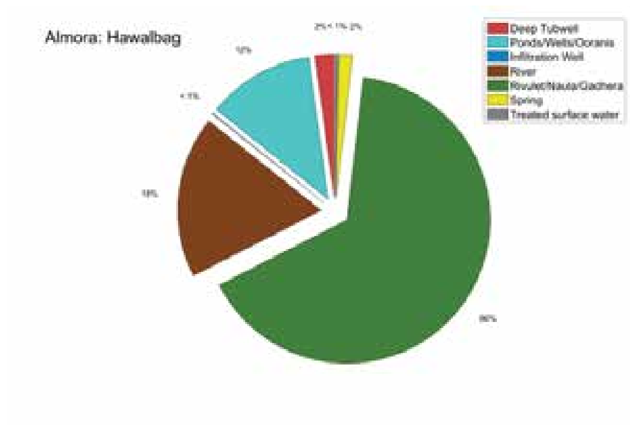

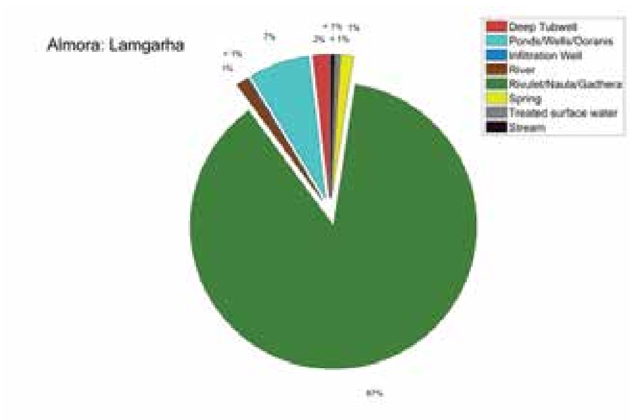

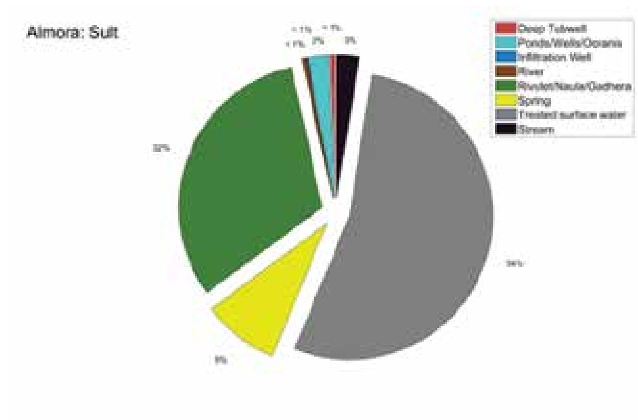

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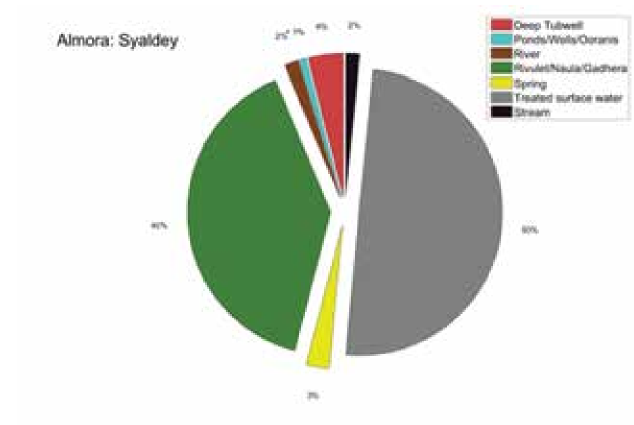
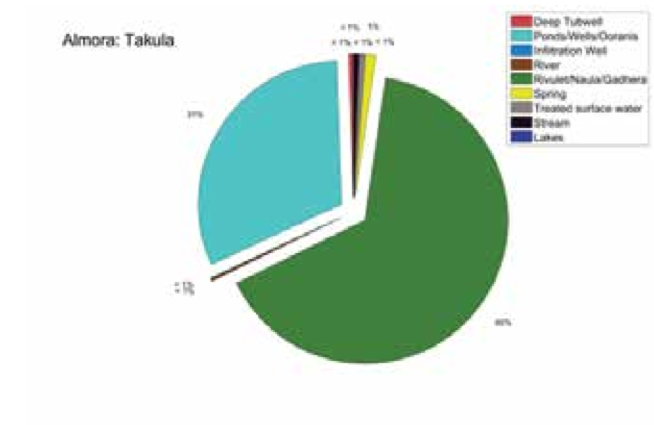
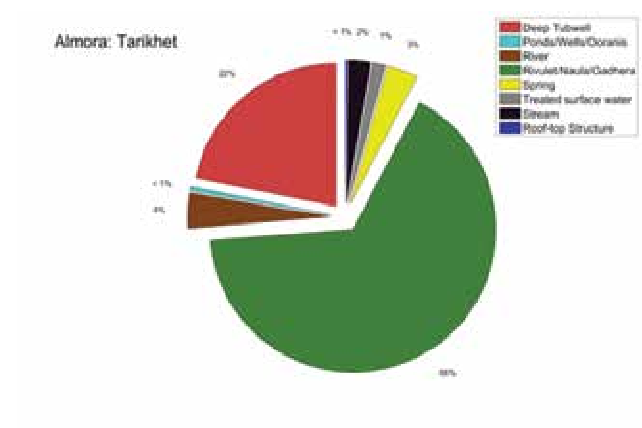
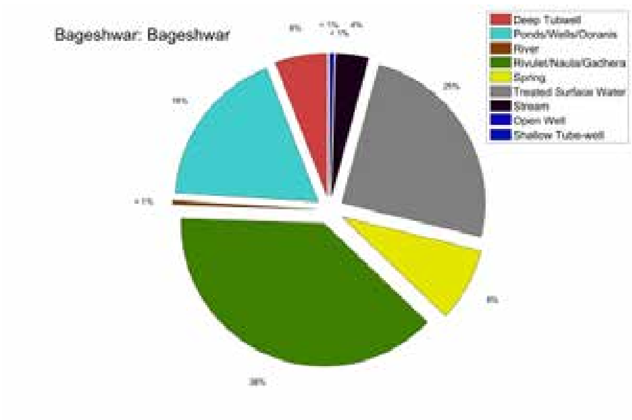
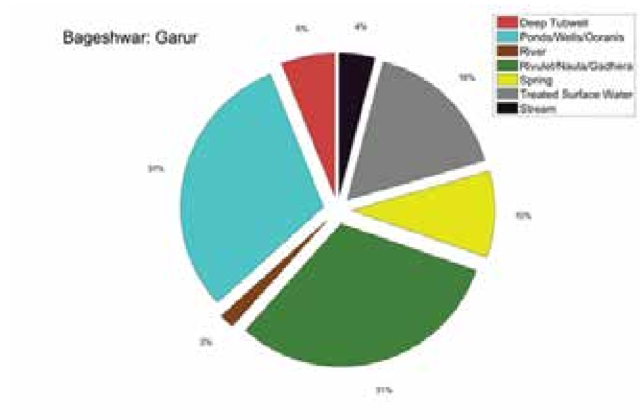


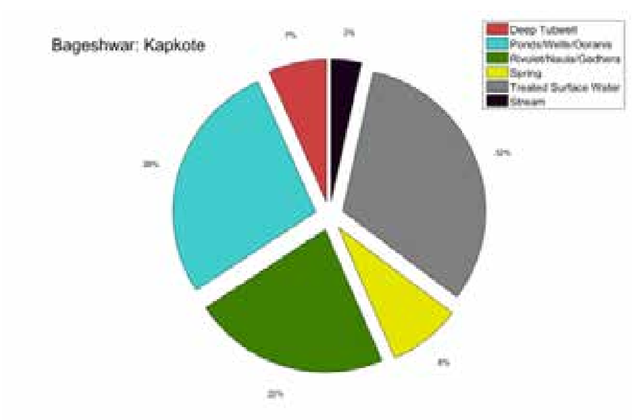




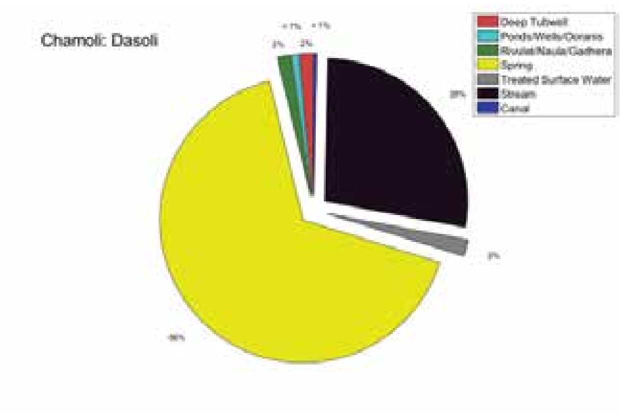
Annexure2: *Block-wise distribution of water sources in the Bageshwar district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

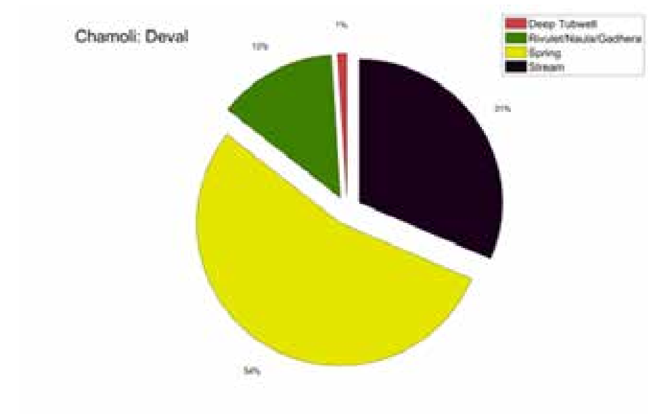


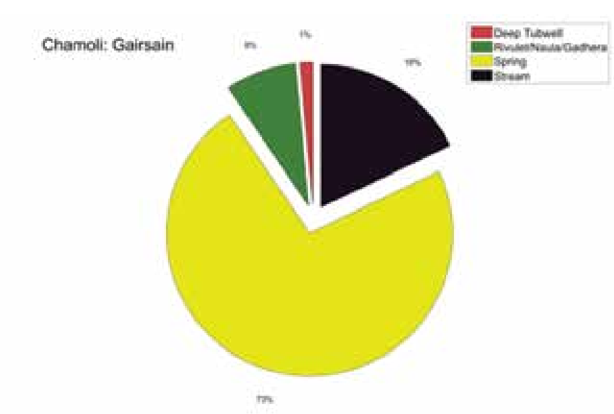


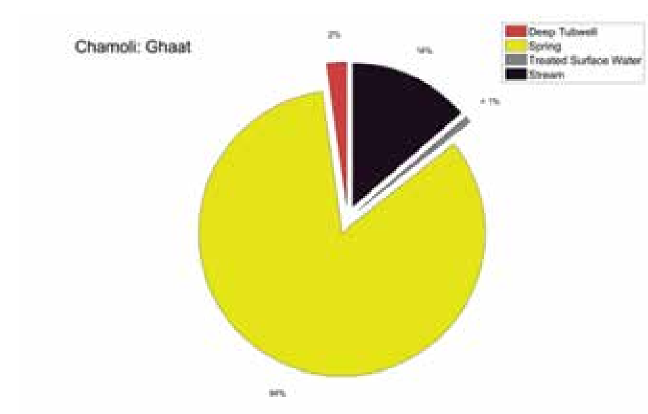


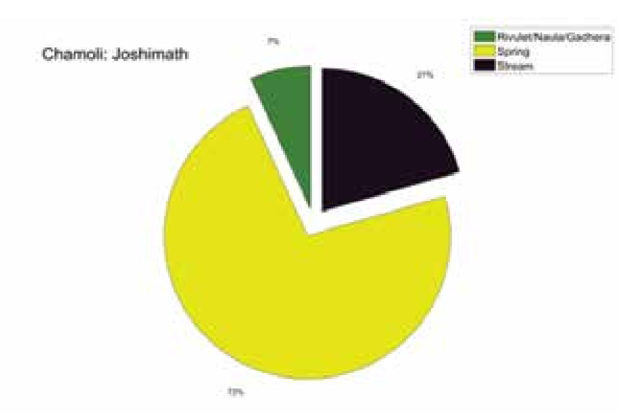
Annexure3: *Block-wise distribution of water sources in the Chamoli district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

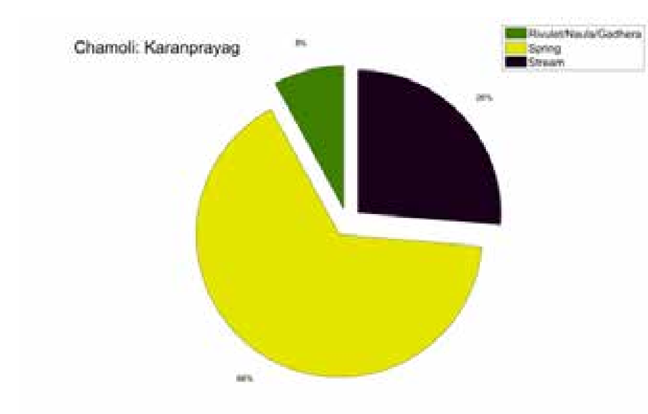




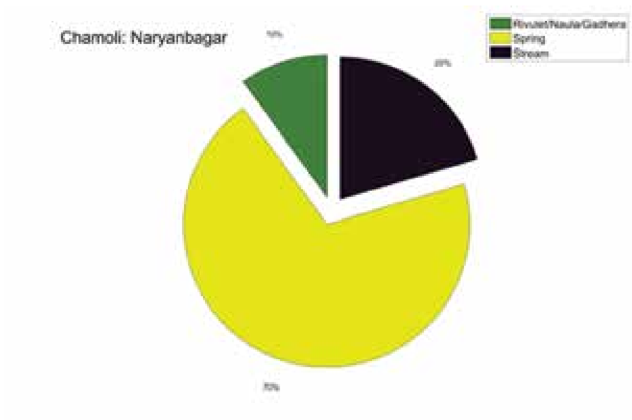


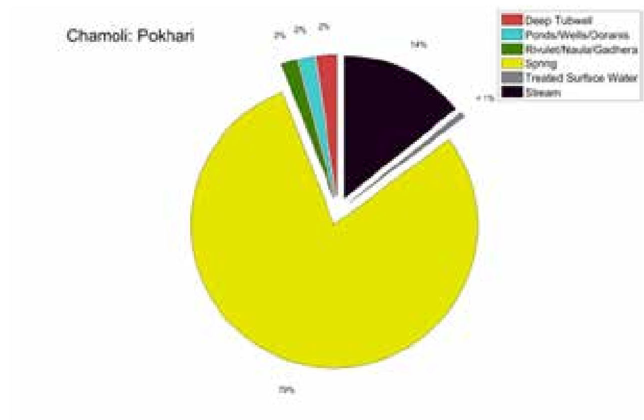


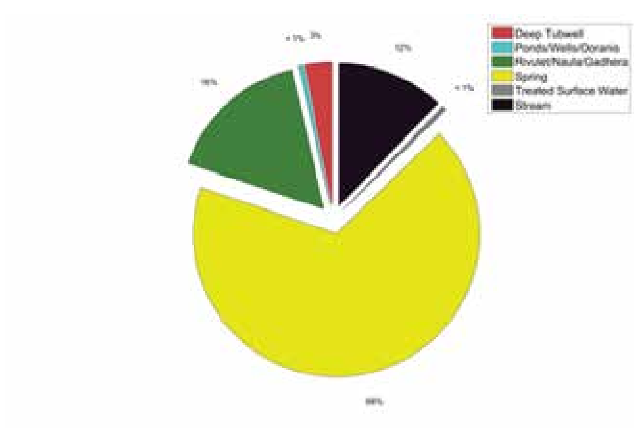




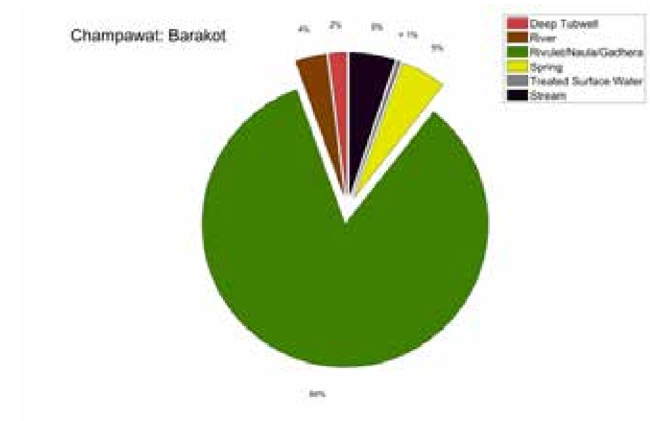
__Annexure3:__ Block-wise distribution of water sources in the Chamoli district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal

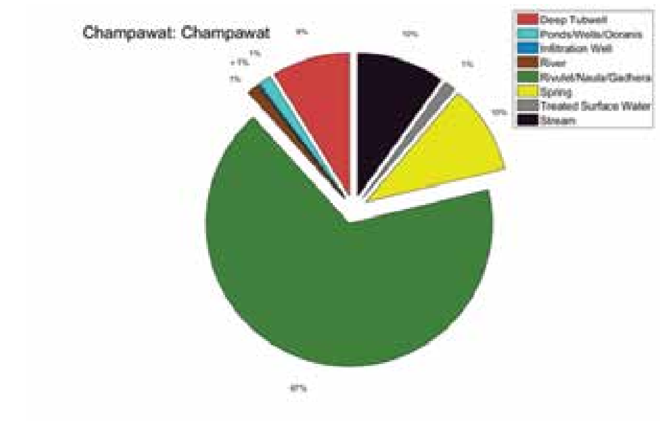


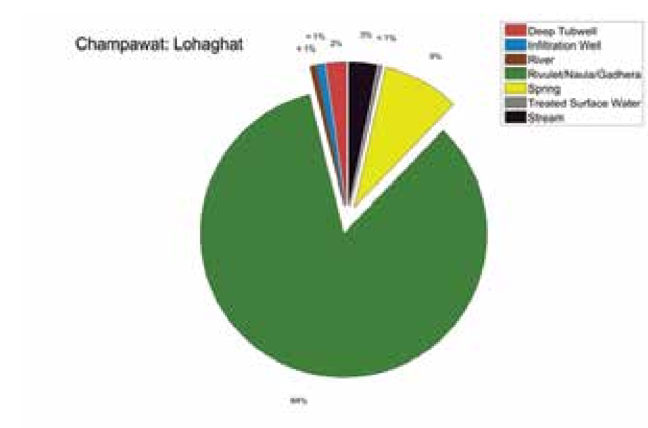


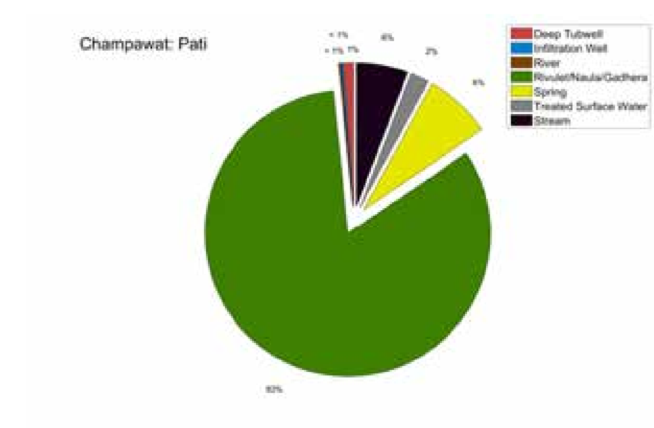


__Annexure4:__ Block-wise distribution of water sources in the Champawat district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal

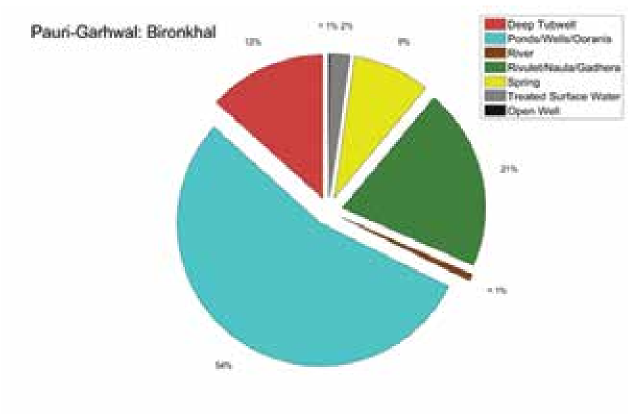


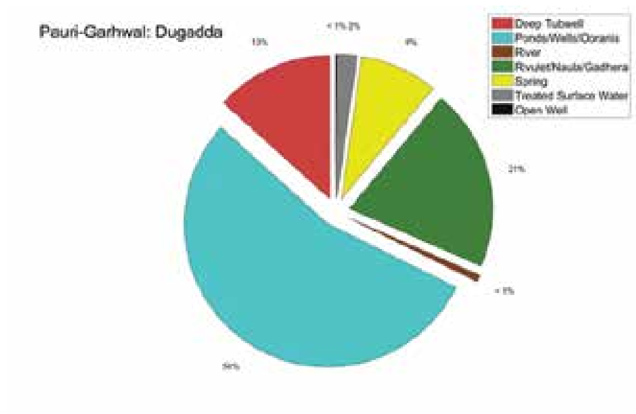


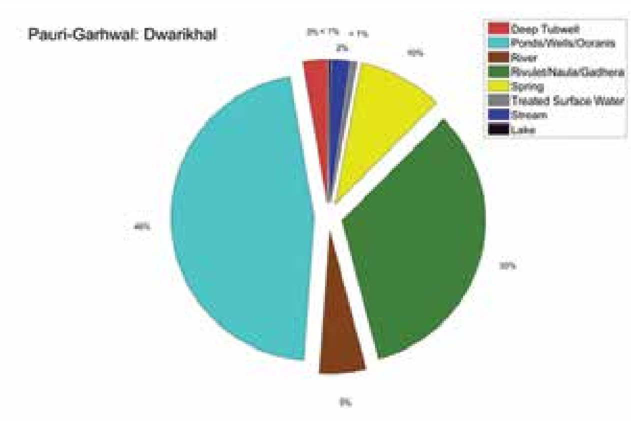


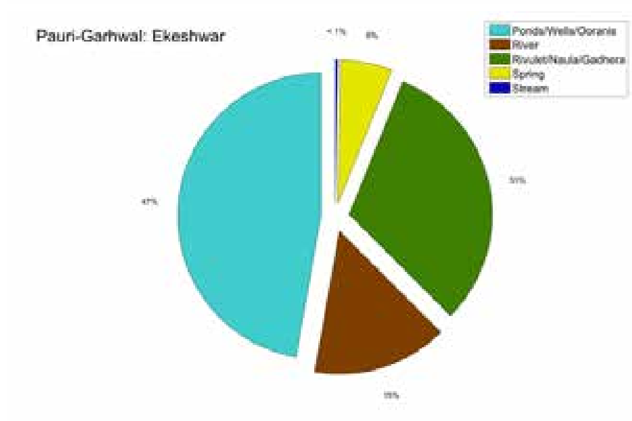


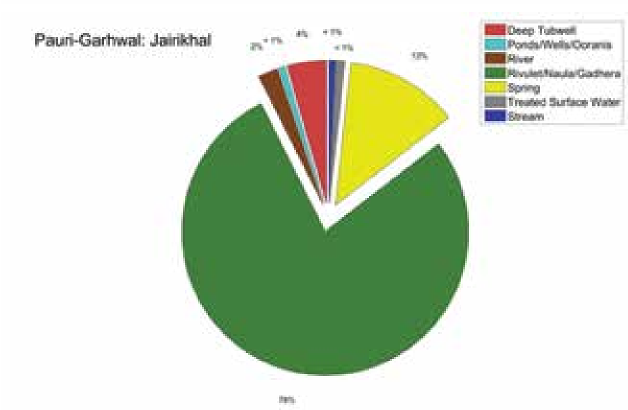
Annexure5: *Block-wise distribution of water sources in the Pauri-Garhwal district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

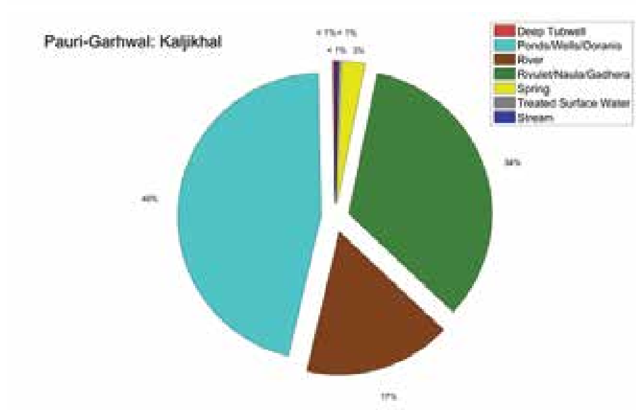


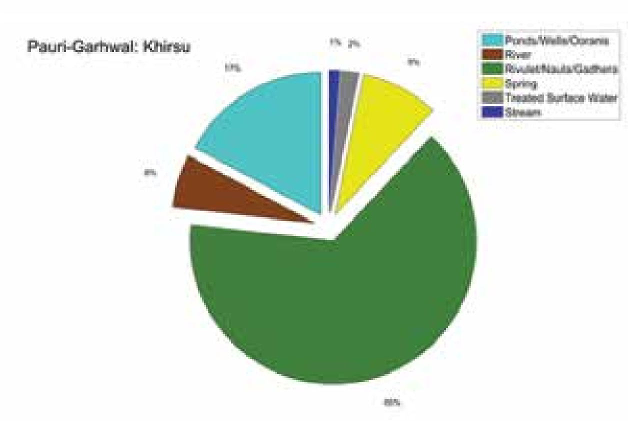


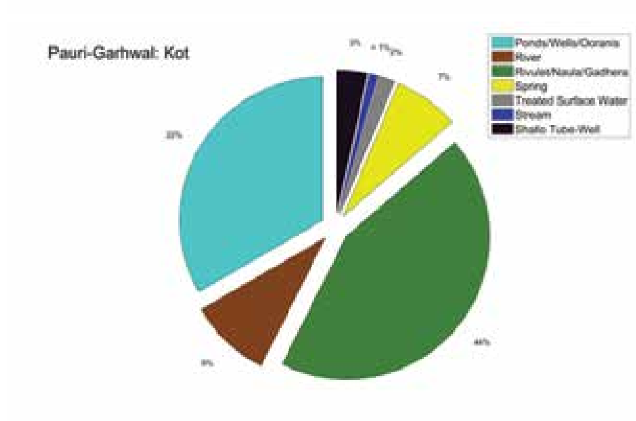




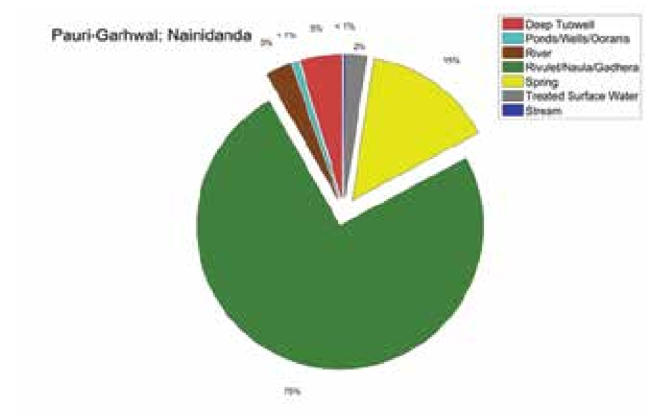


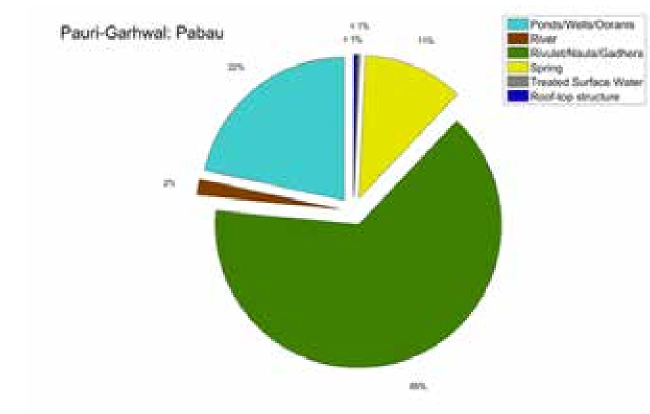


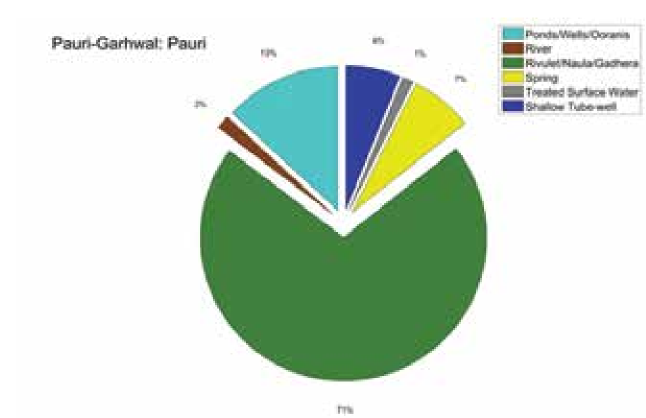


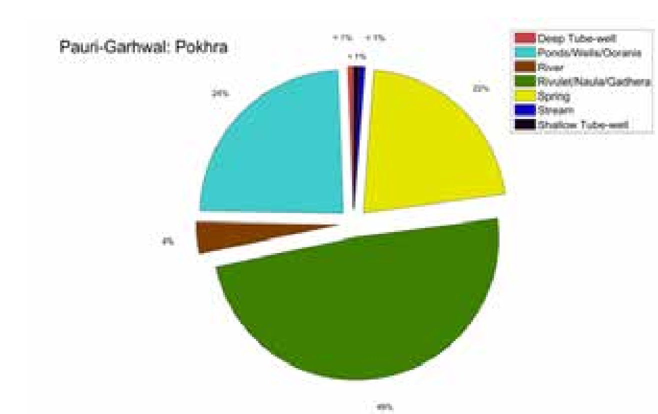


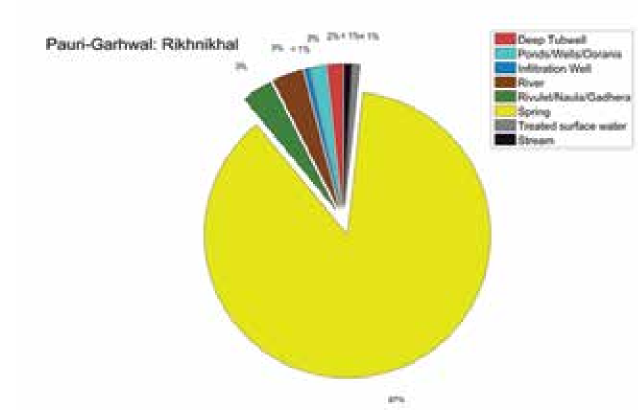
Annexure5: *Block-wise distribution of water sources in the Pauri-Garhwal district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

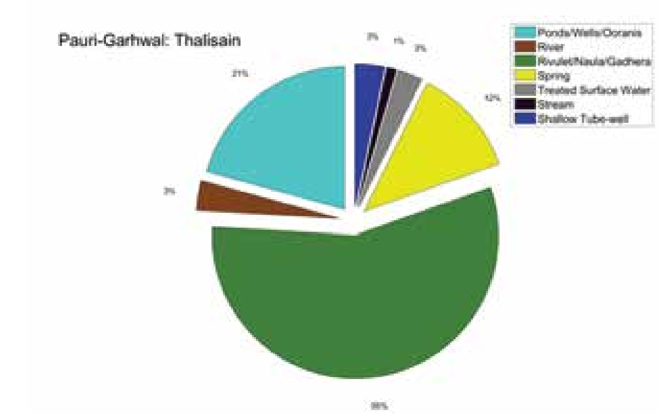


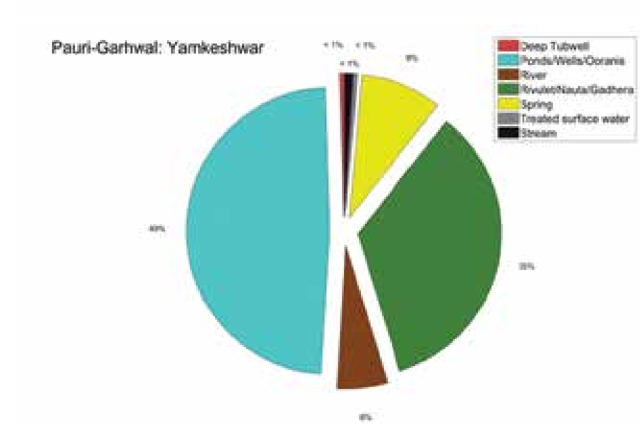




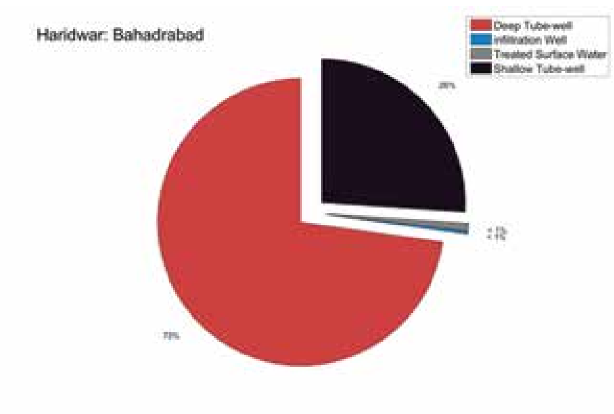


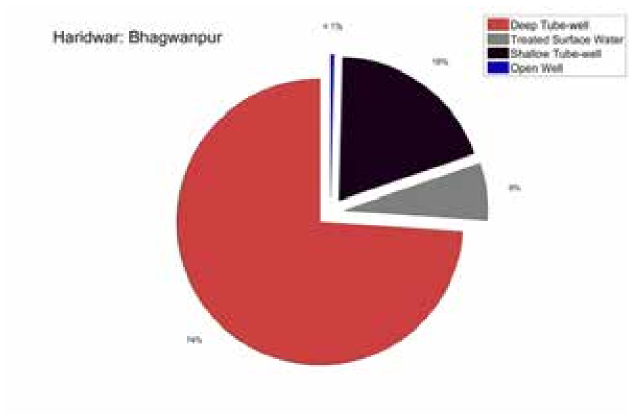


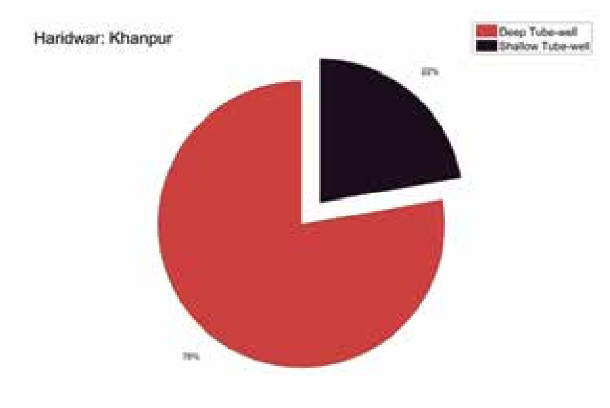


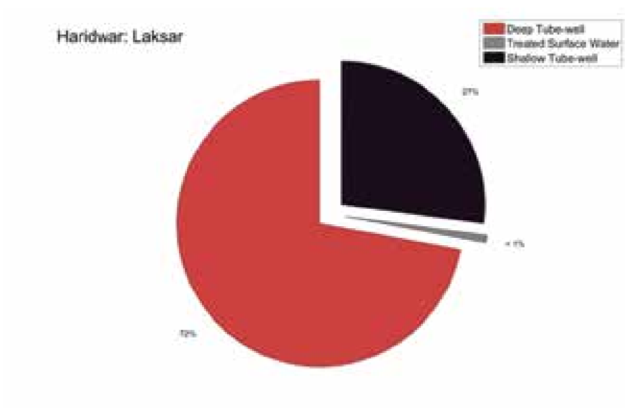


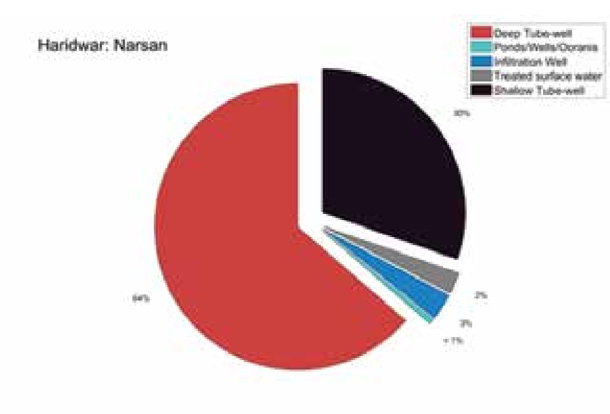
Annexure6: *Block-wise distribution of water sources in the Haridwar district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

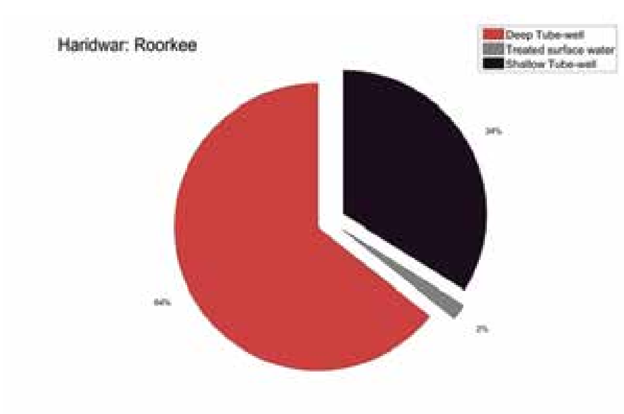




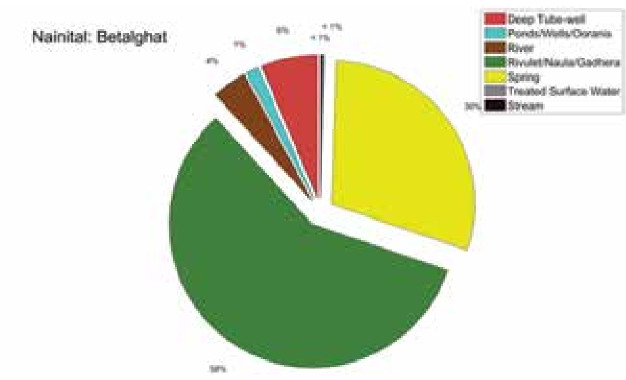


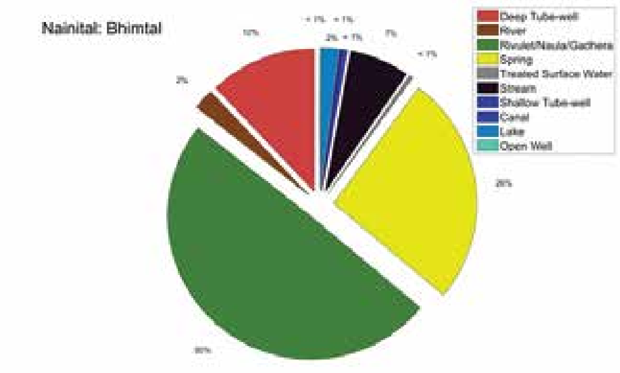


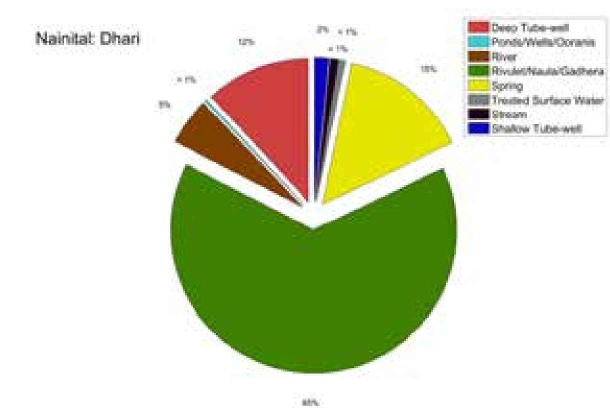


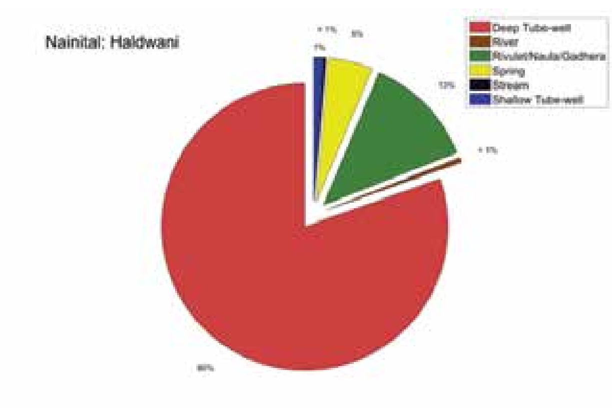


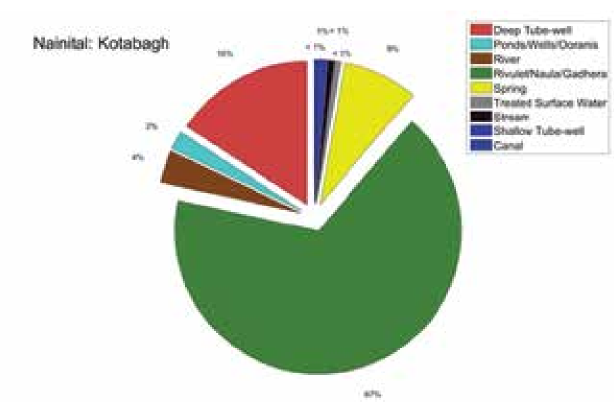
Annexure7: *Block-wise distribution of water sources in the Nainital district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

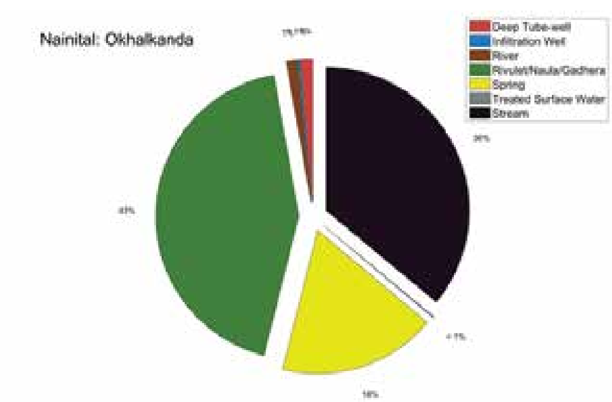


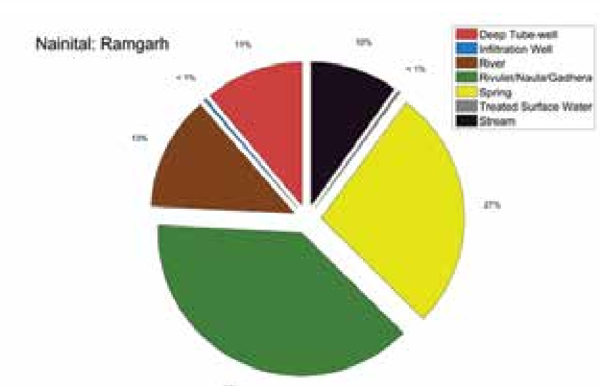


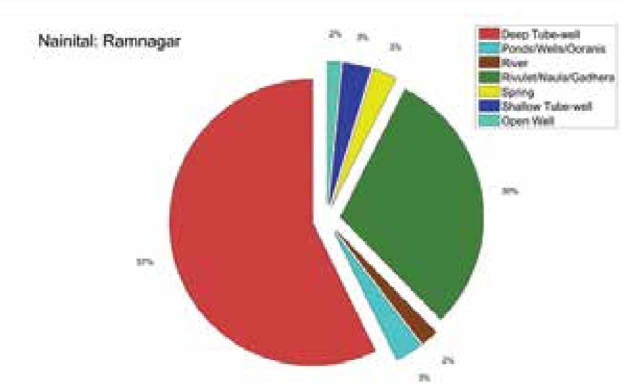




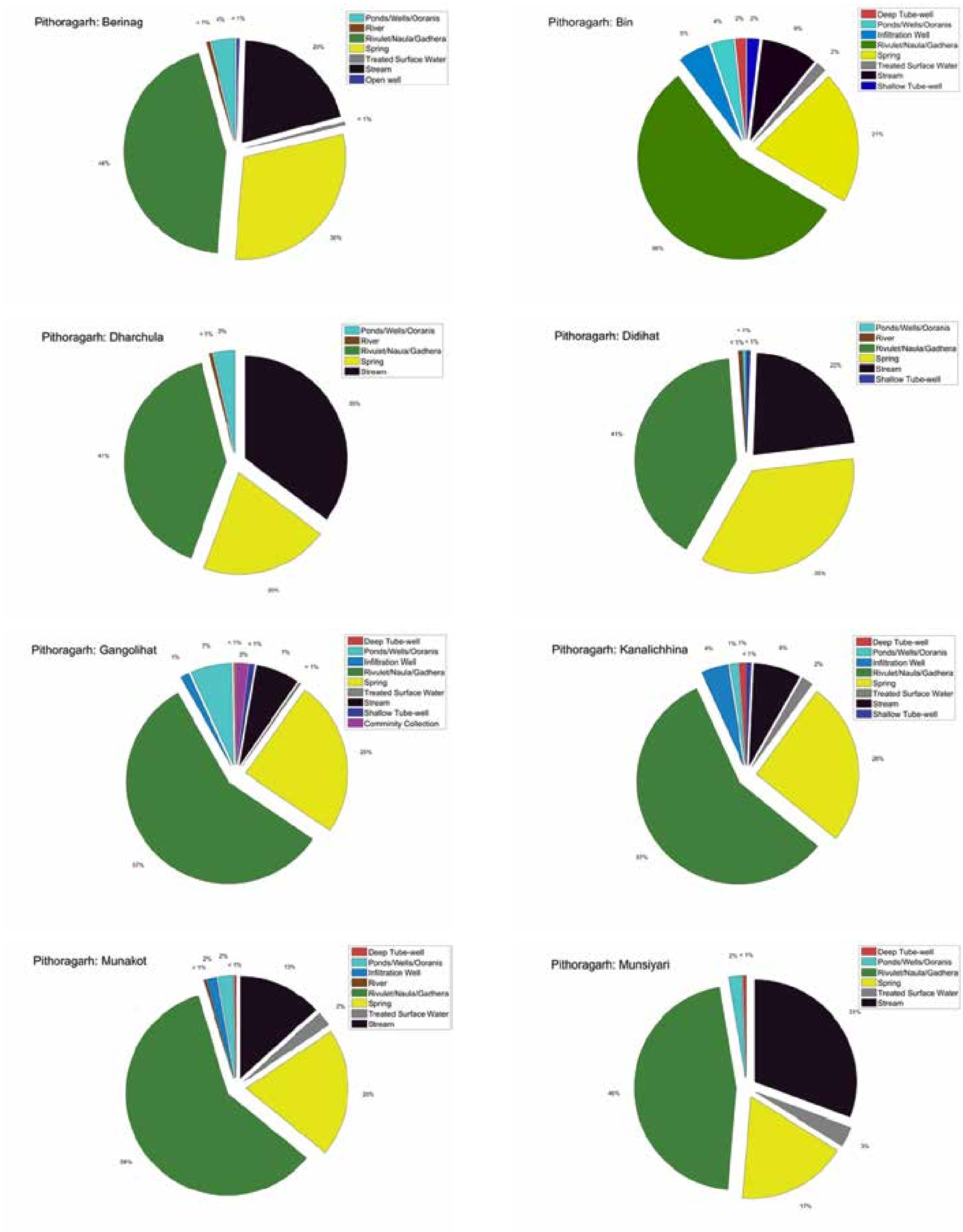




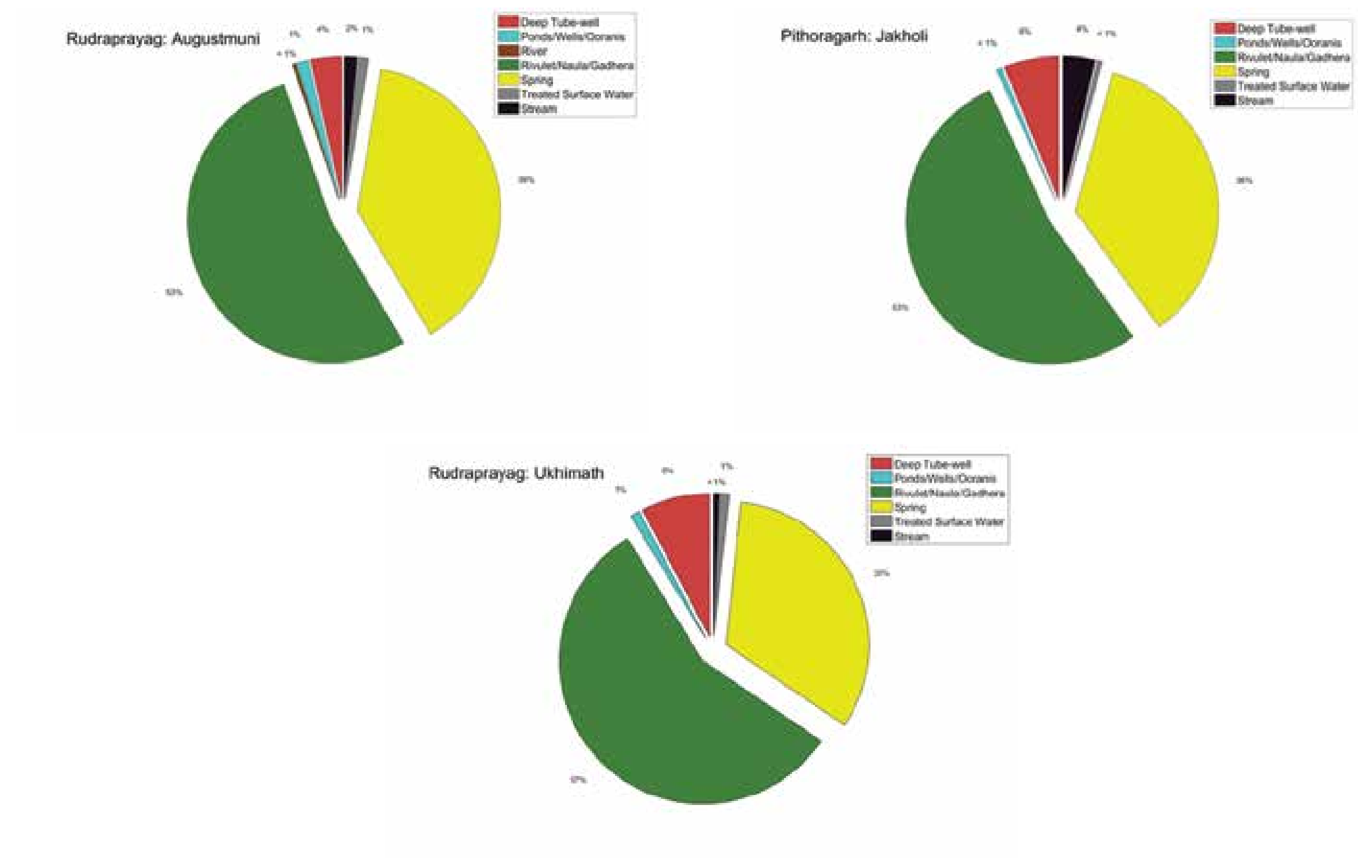




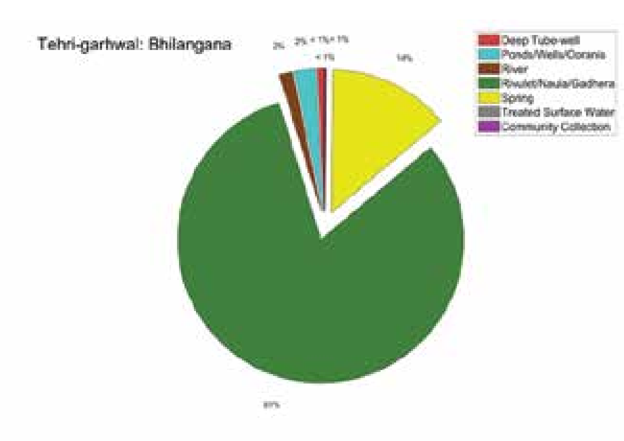
Annexure8: *Block-wise distribution of water sources in the Pithoragarh district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

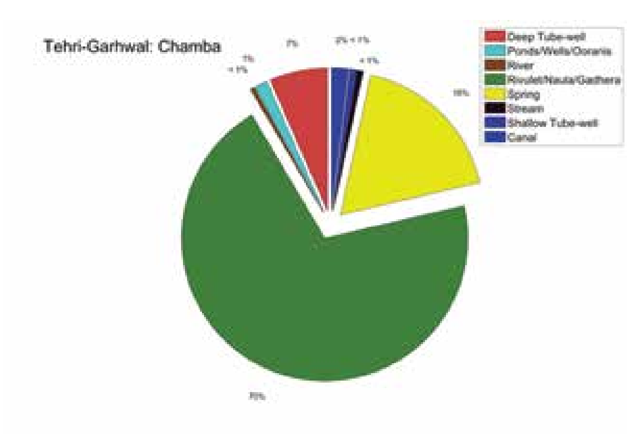


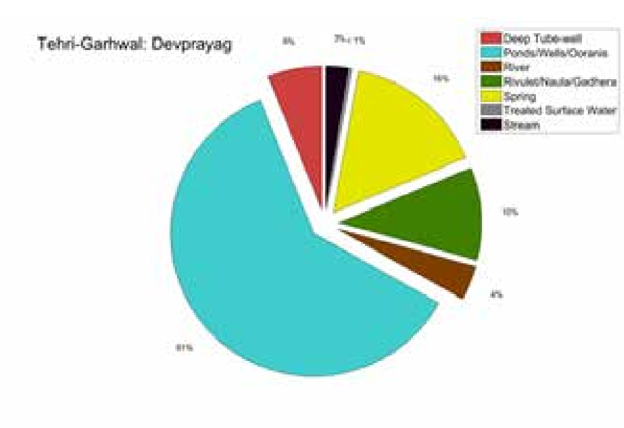
Annexure9: *Block-wise distribution of water sources in the Augustmuni district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

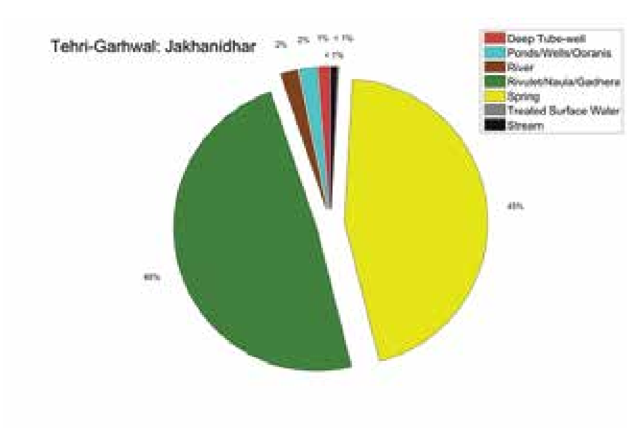


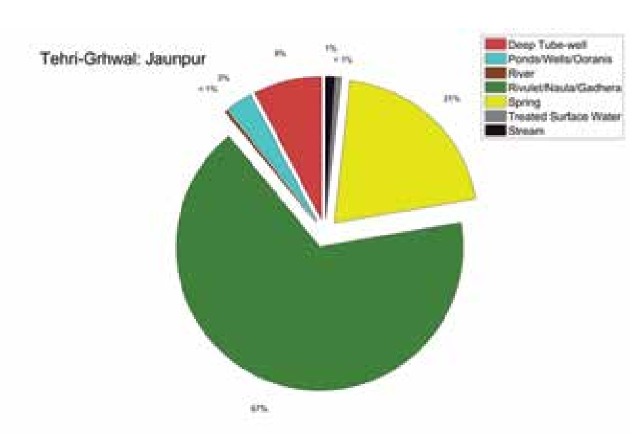
Annexure10: *Block-wise distribution of water sources in the Tehri-Garhwal district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

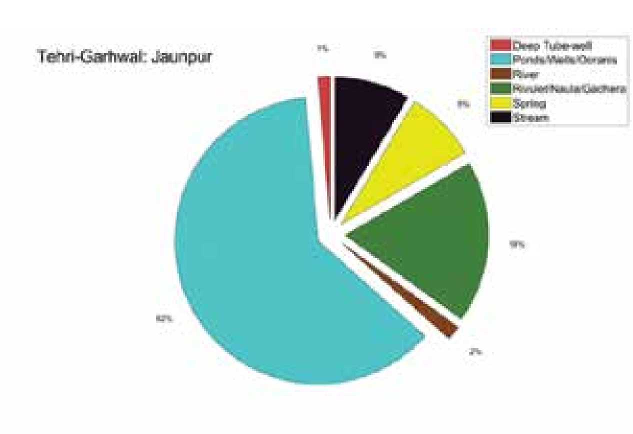




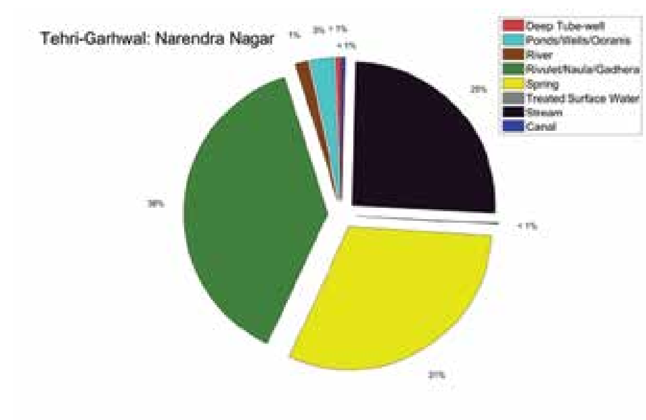


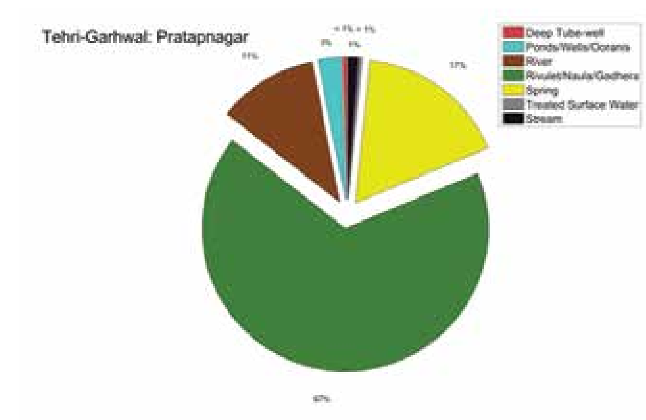


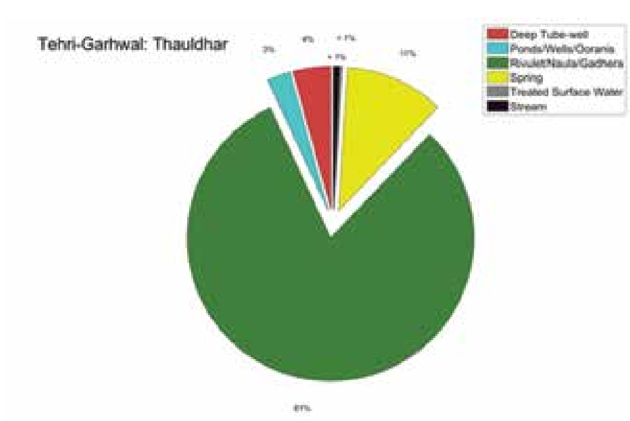




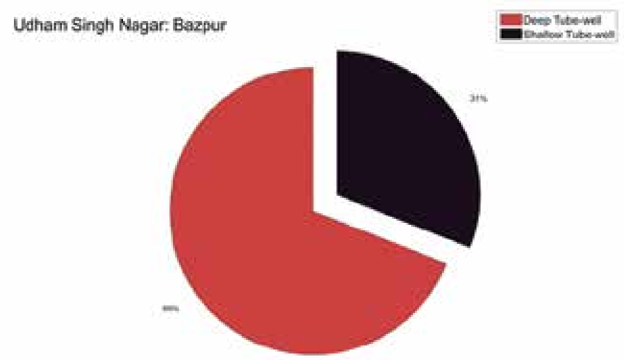
Annexure10: *Block-wise distribution of water sources in the Tehri-Garhwal district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

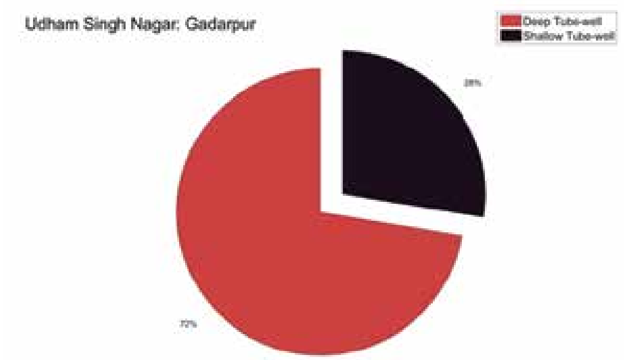


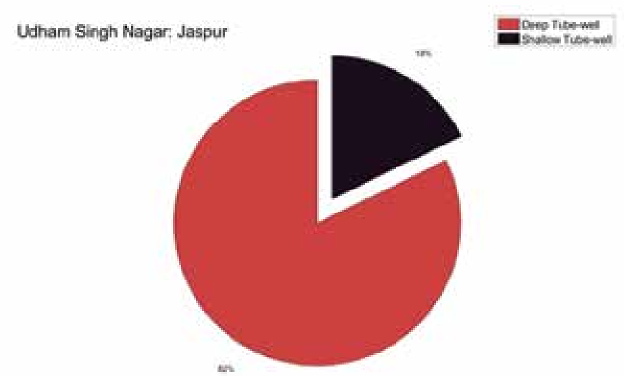


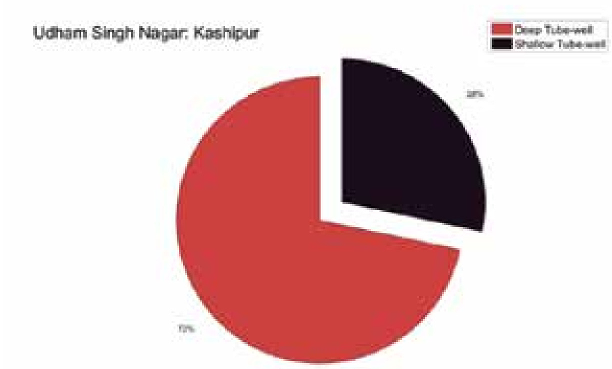


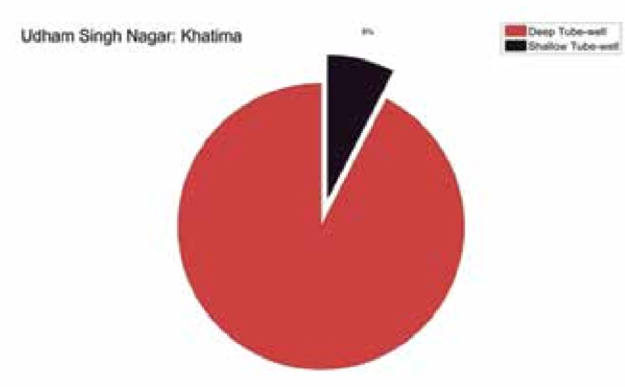
Annexure11: *Block-wise distribution of water sources in the Udham Singh Nagar district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

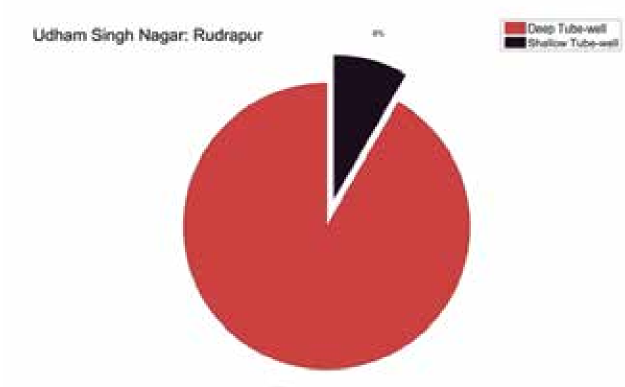


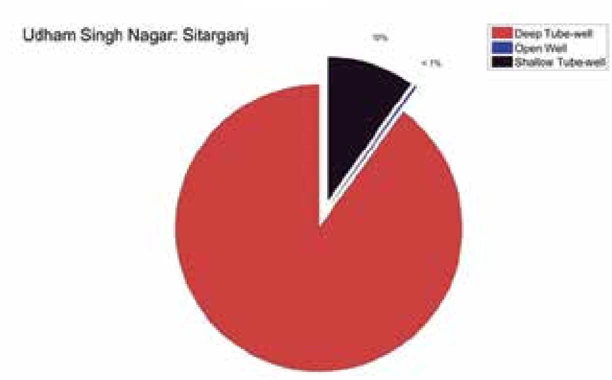




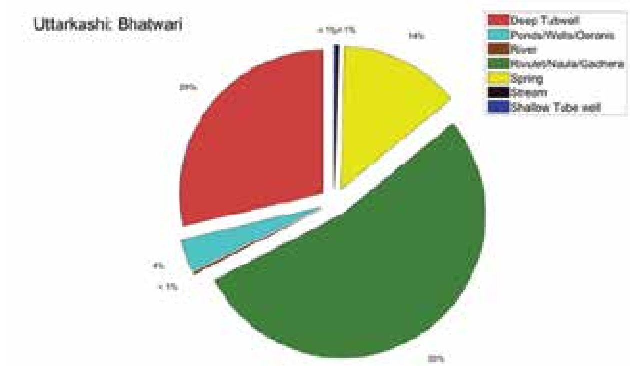


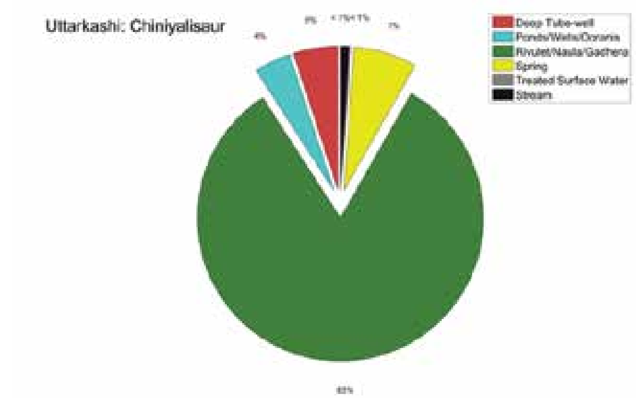


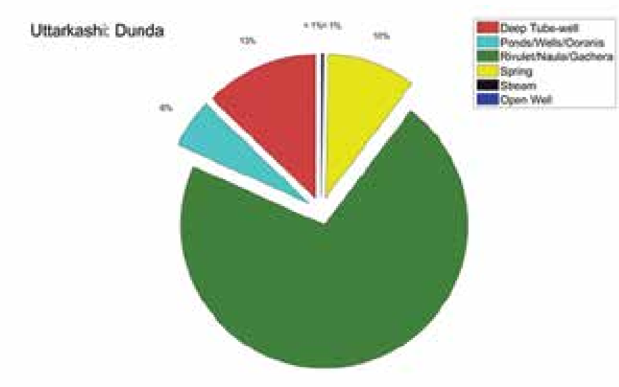


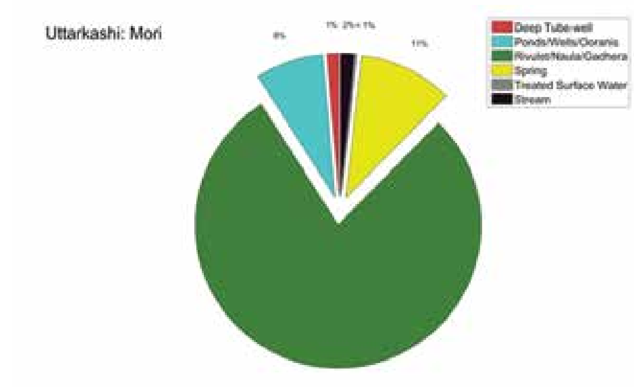


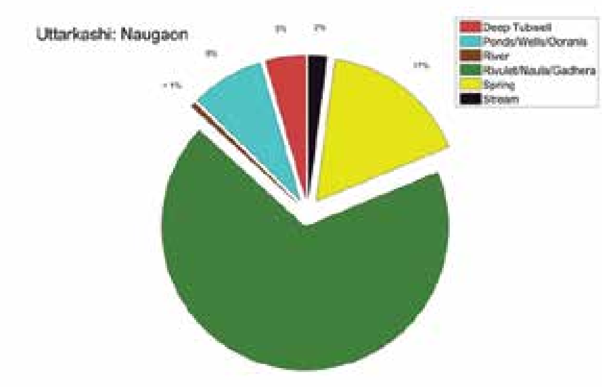
Annexure12: *Block-wise distribution of water sources in the Uttarkashi district of Uttarakhand used for water supply by governmental agencies. Data source: IMIS portal*

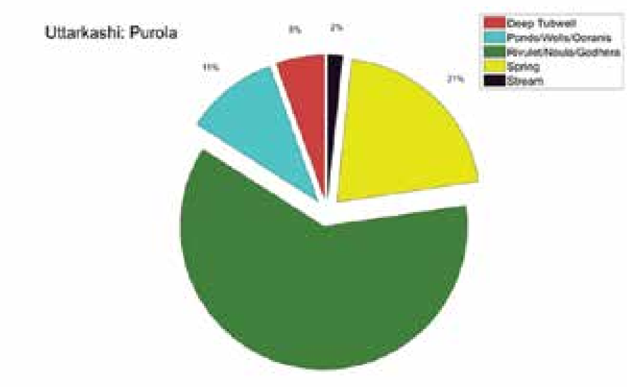












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